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665

TECHNICAL MEMORANDUM NO. 2
OU-2 SUBSURFACE IM/IRA
SOIL VAPOR EXTRACTION PILOT TEST
OFFGAS TREATMENT ALTERNATIVES EVALUATION

Rocky Flats Plant

(Operable Unit No. 2)

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

JULY 1994

ADMIN RECORD

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Page

LIST OF TABLES

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

LIST OF ACRONYMS

AOP	Advanced oxidation process
APEN	Air Pollution Emission Notice
ASME	American Society of Mechanical Engineers
BGS	below ground surface
BH	borehole
BTU	British Thermal Unit
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHC	chlorinated hydrocarbon
CMS/FS	Corrective Measure Study/Feasibility Study
DCA	dichloroethane
DCE	dichloroethene
DOE/RFO	Department of Energy/Rocky Flats Office
DRE	destruction removal efficiency
EPA	Environmental Protection Agency
GAC	granular activated carbon
HAP	hazardous air pollutant
HEPA	high efficiency particulate air
Hz	hertz
IHSS	Individual Hazardous Substance Site
IM/IRAP	Interim Measure/Interim Remedial Action Plan
kg	kilogram
kW	kilowatt
MACT	Maximum Achievable Control Technology
NAPL	non-aqueous phase liquid
NSR	New Source Review
O&M	Operation and Maintenance
OU-2	Operable Unit No 2
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl (PCB)
PCE	tetrachloroethene
PFD	Process Flow Diagram
PID	photoionization detector
PPE	personal protection equipment
PSD	Prevention of Significant Deterioration
psi	pounds per square inch

RACT	Reasonably Available Control Technology
RCRA	Resource Conservation and Recovery Act
RFA	Rocky Flats Alluvium
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
scfm	standard cubic feet per minute
SPSH	six-phase electrical soil heating
SVE	Soil Vapor Extraction
SVOC	semi-volatile organic compound
TCA	trichloroethane
TCE	trichloroethene
TM	Technical Memorandum
tpy	tons per year
TSD	treatment, storage, disposal
UHSU	upper hydrostratigraphic unit
UTL	upper tolerance limit
UV	ultraviolet
V	volt
VOC	Volatile Organic Compound
°F	Fahrenheit
μg	microgram

1.0 INTRODUCTION

The objective of Technical Memorandum No 2 is to identify, evaluate, and select an appropriate offgas treatment technology for removal of VOCs from extracted soil gas The primary criteria for this selection is that it meets performance standards for applications planned at OU-2, Pilot Test Sites No 1 and No 2

The review addresses the existing SVE pilot unit and the additional system design requirements for thermally enhanced removal of organics using Six-Phase Electrical Soil Heating (SPSH) Nonaqueous phase liquids (NAPLs) identified in the subsurface soils from previous drilling programs have the potential to exceed the existing capacity of the offgas treatment system using Granular Activated Carbon (GAC).

An important secondary criteria is that the design meets the potential requirements of future offgas treatment applications for additional SVE programs at the Rocky Flats Plant (RFP) site This requires the treatment system to be portable, to be able to efficiently treat a broad range of contaminant concentrations, and to be an established and proven technology at the size or capacity being considered The scope of identification, evaluation, and selection of the treatment system is limited to technologies which can be retrofitted to the existing SVE pilot unit and operated in a self-contained manner

1.1 PROJECT OVERVIEW

In September 1992, the Department of Energy/Rocky Flats Office (DOE/RFO) released a final subsurface Interim Measure/Interim Remedial Action Plan (IM/IRAP) to investigate the removal of volatile organic compound (VOC) contamination from three areas within Operable Unit 2 (OU-2) Specifically, the SVE technology would be pilot tested within, or adjacent to, suspected VOC source areas in the 903 Pad, Mound, and East Trenches The Final Pilot Test Plan for the SVE technology was submitted to the Colorado Department of

Health (CDH) and Environmental Protection Agency (EPA) in January 1993, for Pilot Test Site No 1 at the East Trenches (DOE 1993a)

In 1993, a pilot SVE unit using GAC for offgas treatment was fabricated off site The unit was installed at Trench T-3, Individual Hazardous Substance Site (IHSS) 110 within OU-2 Pilot Test No 1 is currently in progress. Pilot Test Site No. 2, scheduled for Spring 1995, will incorporate SPSH with the SVE technology

In support of the pilot tests, this document is prepared to identify and evaluate the requirements for an alternative offgas treatment system This system would be used with the existing SVE pilot unit and the SPSH system Technical Memorandum (TM) No 2 will identify and recommend an alternative offgas treatment system to be designed and purchased to support the SVE pilot tests The potential sitewide application of the SVE system and alternative offgas treatment will also be evaluated

1.2 MEMORANDUM OBJECTIVES

The purpose of this technical memorandum is to identify, evaluate, and recommend an offgas treatment system to support the SPSH and SVE technology pilot tests. The memorandum objectives include the following

- Review and summarize the objectives for the IM/IRAP, Pilot Test Site No 1, Pilot Test Site No 2, and any additional pilot tests

- Review and summarize the nature and extent of contamination at the pilot test site

- Define the air emission standards or limits that the offgas treatment system would be required to achieve

- Identify the design criteria for an offgas treatment system for the SVE and six-phase heating technologies

- Evaluate various offgas treatment systems with respect to effectiveness, implementability and cost The implementability criteria will include reliability, compatibility with the existing SVE unit, technology maturity, operation and maintenance requirements, and adverse impacts.

- Identify by-products from the SVE, SPSH, and offgas treatment systems

- Develop alternatives for offgas treatment

- Identify required modifications to the existing SVE pilot system.

- Identify and recommend an offgas treatment alternative to support the pilot tests

1.3 ORGANIZATION

TM No. 2 is organized into eight sections including references and appendixes.

- Section 1 0, Introduction, presents the project overview, the memorandum objectives, and project organization.

- Section 2.0, Evaluation Approach and Pilot Test Objectives, presents the approach for developing and evaluating the offgas treatment alternatives, IM/IRAP objectives, and the pilot test objectives

- Section 3.0, Pilot Test Site Subsurface Conditions, presents the nature and extent of contamination at the pilot test site, soil characteristics, and soil gas survey results.

- Section 4 0, Basis of Design for Offgas Treatment, presents the design and operating criteria for the SVE system, design criteria, and air emission limits for an offgas treatment system

- Section 5.0, Technology Identification and Screening, presents offgas treatment technologies and an evaluation or screening of these technologies with respect to effectiveness and implementability

- Section 6.0, Development and Evaluation of Alternatives, presents a summary of the design basis and alternatives for offgas treatment This section will present cost estimates associated with these alternatives This section will also present a brief summary of the report and recommends an offgas treatment alternative.

- Section 7.0 contains the references

- The Appendix will contain capital and O&M costs for each alternative

2.0 EVALUATION APPROACH AND PILOT TEST OBJECTIVES

The following sections identify the approach for developing and evaluating the offgas treatment alternatives and also present the objectives of the Pilot Test Sites No 1 and No 2

2.1 OFFGAS TREATMENT EVALUATION APPROACH

A design basis will be developed to evaluate potential alternatives for offgas treatment for SVE and SPSH This design basis will include the site subsurface conditions, the design criteria for the existing SVE system and SPSH, regulatory requirements, site-specific criteria, and any waste management restrictions The subsurface conditions have been identified during the Phase I and Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) and soil gas surveys performed as part of the SVE Pilot Test Site No 1

Potentially applicable offgas treatment technologies will be identified, described, and evaluated with respect to effectiveness and implementability This evaluation will involve a review and screening of each technology and identification of retained technologies for evaluation and consideration as a treatment alternative

Each of the retained technologies will be developed into alternatives The alternatives will be conceptual level designs identifying all major pieces of equipment, power requirements, utilities needed; and generation, treatment, and disposal of by-products The alternatives will be developed in conformance to the design criteria and to meet the treatment objectives Capital and Operating and Maintenance (O&M) costs will be estimated for each alternative The alternatives will then be evaluated with respect to effectiveness, implementability, and cost A comparison of alternatives will be performed and a preferred alternative will be recommended for further design

2.2 IM/IRAP OBJECTIVES

The IM/IRAP objective was to investigate the removal of VOC contamination in suspected subsurface areas at OU-2 using SVE technology The IM/IRAP had identified three locations to test SVE technology 903 Pad, Mound, and East Trenches Pilot Test Sites No 1 and No. 2 are discussed below

2.3 PILOT TEST SITE NO. 1 OBJECTIVES

Pilot Test Site No 1 for the SVE technology was selected based on soil gas survey data and known contamination at this particular site The following are overall objectives of the pilot study

- Assess the SVE technology for removal of VOCs in the Rocky Flats Alluvium (RFA) formation
- Assess the SVE technology for removal of VOCs in sandstone with groundwater extraction
- Assess active versus passive air injection.
- Incorporate information into the Corrective Measure Study/Feasibility Study (CMS/FS).
- Minimize adverse effects to environment during the pilot test

2.4 PILOT TEST SITE NO. 2 OBJECTIVES

The purpose of the Pilot Test Site No. 2 for SPSH is to determine if this technology is a cost effective means of enhancing conventional SVE for removal of VOCs at the Rocky Flats site.

The following overall objectives of the pilot study are

- Assess the ability of SPSH to accelerate the rate of removal of VOCs over conventional SVE at the Rocky Flats site
- Assess the ability of SPSH to increase the extent of removal over conventional SVE of VOCs existing with inhibiting co-contaminants at the Rocky Flats site
- To collect sufficient data to project economic feasibility and O&M reliability of additional applications of SPSH-SVE at other Rocky Flats sites.

3.0 PILOT TEST SITE SUBSURFACE CONDITIONS

The location for Pilot Test Sites No 1 and No 2 is Trench T-3 (IHSS 110) as shown on Figure 3 1-1, which is located north of Central Avenue, east of the inner fence, and south of South Walnut Creek Trench T-3 was used from 1954 to 1963 for burial of sanitary sewage sludge contaminated with depleted uranium and plutonium in addition to flattened drums contaminated with depleted uranium The nature and extent of contamination within subsurface soils and soil gas in the vicinity of Trench T-3 are discussed below.

3.1 SUBSURFACE SOILS

Three source boreholes, three plume characterization monitoring wells, one pilot borehole, and seven SVE locations were drilled and sampled during Phase I, Phase II, and SVE investigations to characterize the vertical extent of contamination in Trench T-3 (10191, 02991, 12191, 21693, 22493, BH3987, BH4087, 24093, 24193, 24493, 24593, 24693, 24793, and 25093) The subsurface soil sample results from these boreholes and wells were used in the statistical detection frequency calculations (Table 3 1-1 and Figures 3 1-2, and 3 1-3,)

VOCs

Seventeen VOCs were detected in subsurface soil samples collected within Trench T-3 (IHSS 110), as shown on Table 3 1-1 Some of these are suspected laboratory and field contaminants (see the OU-2 Phase II RFI/RI report [DOE 1993b] for further discussion); (acetone, toluene, methylene chloride, and 2-butanone) Free product was observed in borehole 10191 at a depth of 4 2 feet during drilling Source borehole 10191 exhibited elevated levels of 1,1,1-trichloroethane (TCA), carbon tetrachloride (CCl_4), chloroform ($CHCl_3$), tetrachloroethene (PCE), and trichloroethene (TCE) in the samples collected above the initial water at the time of drilling In general, the concentrations of the chlorinated hydrocarbons (CHCs) decreased with depth in the vadose zone in source borehole 10191

TABLE 3.1-1

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Volatile Organic Compounds (µg/kg)						
Acetone	NA	57	30	52 6%	1085 - 96,000	7,511
Toluene	NA	58	33	56 9%	5J - 7,600	465
Methylene chloride	NA	58	15	25 9%	45 - 20	8 8
2-Butanone	NA	58	9	15 5%	40J - 140	67 1
1,1,1-Trichloroethane	NA	58	9	15 5%	6 - 27,000	8047
Carbon tetrachloride	NA	58	19	32 8%	3J - 700,000	62,964
Chloroform	NA	58	17	29 3%	1J - 8800	536
Tetrachloroethene	NA	58	28	48 3%	1J - 13,000,000	1,037,989
Trichloroethene	NA	58	7	12 1%	1J - 120,000	18,303
1,1-Dichloroethene	NA	58	1	1 7%	9	9
1,2-Dichloroethane	NA	58	4	6 9%	6J - 15J	11 7
1,2-Dichloroethene	NA	58	1	1 7%	1J	1
2-Propenoic acid, 2-methyl	NA	1	1	100 0%	6J	6
Ethylbenzene	NA	58	1	1 7%	2J	2
Methyl methacrylate	NA	1	1	100 0%	6J	6
Styrene	NA	58	1	1 7%	2BJ	2
Total xylenes	NA	58	1	1 7%	7BJ	7

TABLE 3 1-1 (Continued)

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Semivolatile Organic Compounds (µg/kg)						
Bis(2-ethylhexyl)phthalate	NA	21	20	95 2%	51J - 5500	503 8
Di-n-butyl phthalate	NA	21	1	4 8%	1300J	1300
Phenanthrene	NA	21	1	4 8%	2700J	2700
N-nitrosodiphenylamine	NA	21	1	4 8%	33J	33
2-Methylphenol	NA	21	1	4 8%	450	450
4-Methylphenol	NA	21	1	4 8%	2900	2900
Hexachlorobutadiene	NA	21	1	4 8%	170J	170
Hexachloroethane	NA	21	2	9 5%	370-1100	735
2-Methylnapthalene	NA	21	1	4 8%	8100D	8100
Naphthalene	NA	21	1	4 8%	2000	2000
Pesticides/PCBs (µg/kg)						
Aroclor-1254	NA	21	1	4 8%	6900D	6900

TABLE 3 1-1 (Concluded)

ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Radionuclides above background UTLs (pCi/g)(5)						
Americium-241	0 01	21	12	57 1%	0 01 - 0 5983	0 090
Plutonium-239	0 02	12	7	58 3%	0 02 - 1 1	0 209
Plutonium-239/240	0 02	9	8	88 9%	0 02855 - 3 12	0 47
Uranium-238	1 5	9	2	22 2%	1 611 - 26 37	14 0
Uranium-233,234	2 5	9	1	11 1%	14 35	14 35
Uranium-235	0 2	9	1	11 1%	0 7509	0 7509
Strontium-90	0 9	21	3	14 3%	0 9 - 1 1	1 0
Tritium (pCi/l)	366	21	1	4 8%	400	400 00

Locations BH3987, BH4087, 02991, 10191, 12191, 21693, 22493, 24093, 24193, 24493, 24593, 24693, 24793, 25093

NA = not applicable

UTLs = upper tolerance limit

(1) Background concentrations do not exist and are not applicable for organic compounds

(2) For radionuclides, the number of detections represent only detected concentrations exceeding the background 95% UTL

(3) B and J qualifiers represent estimated result, D qualifier represents dilution result

(4) The calculation for the mean concentration includes all J, D, and B qualified data

(5) Only radionuclides detected above the background UTLs are listed Number of detection, percent detections, concentration range, and mean concentration refer only to results exceeding background UTLs

Below the water table, concentrations increased again, but to levels significantly lower than those seen in the vadose zone

Semi-volatile Organic Compounds (SVOCs)

Ten SVOCs were detected in subsurface soil samples collected within Trench T-3, as shown on Table 3.1-1

Pesticides/PCBs

Aroclor-1254, a polychlorinated biphenyl (PCB), was detected at an estimated concentration of 6,900 μg/kg in borehole 10191 from 1 out of 21 samples analyzed, taken at the depth of 4 2 to 8 feet, as shown on Table 3 1-1.

Radionuclides

Eight radionuclides detected at activities above the background upper tolerance limits (UTLs) are presented in Table 3 1-1 Elevated levels of radionuclides are concentrated in the 4 2- to 8-foot interval of borehole 10191 and generally decrease with depth, indicating the source of radionuclides to be within Trench T-3. Trench T-3 is estimated to be between 5 and 10 feet deep

Summary

The subsurface soil analytical data collected from Trench T-3 indicate that it is a source of VOC contamination (1,1,1-TCA, CCl_4, $CHCl_3$, PCE, TCE, and 1,2-DCA) to the subsurface soil and potentially to upper hydrostratigraphic unit (UHSU) groundwater The concentrations of CHCs decrease with depth down to the water table There is minor contamination by polyaromatic hydrocarbons (PAHs) and other SVOCs Elevated activities

of Am-241, Pu-239, Pu-239/240, U-233,234, U-235, and U-238 are also present in Trench T-3

3.2 SOIL GAS

Two soil gas surveys have been performed around Trench T-3 (IHSS 110) Both a shallow and a deeper survey have been carried out The findings of the soil gas surveys are summarized below The shallow (near surface less than a depth of five feet) soil gas survey analyses included the following VOCs:

- 1,1-dichloroethene (DCE)
- trans-1,2-dichloroethene (trans-1,2-DCE)
- cis-1,2-dichloroethene (cis-1,2-DCE)
- 1,1-dichloroethane (DCA)
- 1,2-DCA
- CCl_4
- PCE
- TCE
- Vinyl chloride
- Total VOCs

1,1-DCE, trans-1,2-DCE, cis-1,2-DCE, and 1,2-DCA were not detected in the soil vapor 1,1-DCA was detected in 16 of 35 sampling locations and concentrations ranged from 40 to 1,900 μg/l CCl_4 was detected in 18 of the 35 sampling locations with concentrations ranging from 0 36 to 111 μg/l PCE was detected in 22 of the 35 sampling locations with concentrations ranging from 0 11 to 410 μg/l TCE was detected in 14 of the 35 sampling locations with concentrations ranging from 1 2 to 21 μg/l Vinyl chloride was detected in two sampling locations at concentrations less than 23 μg/l

Review of the spatial distribution of the soil gas data in Trench T-3 indicates that CCl_4 may be found only in the west end of the trench (west of borehole 10191) The PCE soil gas plume is located in the west central part of Trench T-3 (located east of borehole 10191 and around the SVE wells and boreholes). The TCE soil gas plume is similar in location to the PCE plume Two elevated total VOC concentration areas are observed in and around Trench T-3 One is located in the west central part of Trench T-3 (around the SVE wells and boreholes) and the second is located on the western end of Trench T-3 (west of borehole 10191)

The deeper soil gas survey (two surveys from depths of 5 and 10 feet) analytes are shown in Table 3 2-1 and include.

- 1,1-DCA
- CCl_4
- PCE
- TCE
- Total VOCs

Based on the evaluation of the soil gas obtained from the 5-foot sampling intervals, total VOCs appear to be concentrated on the western part of Trench T-3 (around borehole 10191) The CCl_4 soil vapor plume is located west of Trench T-3 boundary, while 1,1-DCA, PCE, and TCE are located at the western end of Trench T-3

Review of the soil gas data obtained from a depth of 10 feet indicates that total VOCs, CCl_4, and PCE were observed at higher concentrations than at the 5-foot depth 1,1-DCA was not detected in the 10-foot sample and TCE was detected at relatively low concentrations

TABLE 3.2-1

OU-2 SUBSURFACE IM/IRA DETAILED SOIL VAPOR SURVEY FIELD REPORT

Location Code	Survey Coordinates		Soil Gas Sample Number	Comment	Sample Depth (ft)	Soil Gas Laboratory Data (μg/L)				
	Easting	Northing				1-1,DCA	CCL_4	TCE	PCE	Total VOCs
111 1-13	2087375	749933	bh36vs01		5 0	0	0	1	0 7	1 7
111 1-14	2087347	749923	bh37vs01		5 0	0	0 47	24	1	25 47
111 1-15	2087319	749912	bh30vs01		5 0	0	11	770	21	802
111 1-16	2087291	749901	bh31vs01		5 0	0	19	514	31	564
111 1-17	2087264	749889	bh19vs01		5 0	14	93	1,023	274	1,404
111 1-18	2087235	749879	bh20vs01		5 0	12	3	2,740	1,670	4,425
111 1-19	2087207	749868	bh23vs02	field replicate	5 0	5 9	0 5	1,670	4,000	5,676 4
111 1-20	2087179	749858	bh24vs01		5 0	0	0 2	110	896	1,006 2
111 1-21	2087150	749849	bh25vs01		5 0	0	0	0 8	4 4	5 2
112-65	2085911	748788	bh40vs01		5 0	0	0 3	4 1	7 7	12 1
112-66	2085908	748814	bh39vs01		5 0	0	0 3	3 2	52	55 5
112-67	2085876	748801	bh38vs01		5 0	0	0	0 97	1 25	2 22
112-68	2085609	749135	bh61vs01		5 0	0	156	1 4	6 8	164 2
112-69	2085616	749035	bh60vs01		5 0	0	90	1 5	5 5	97
112-70	2085615	748975	bh59vs01		5 0	0	21	0 51	2 2	23 71

TABLE 3.2-1
(Concluded)

Location Code	Survey Coordinates		Soil Gas Sample Number	Comment	Sample Depth (ft)	Soil Gas Laboratory Data (µg/L)				
	Easting	Northing				1-1,DCA	CCL_4	TCE	PCE	Total VOCs
112-71	2085661	748957	bh58vs01		5 0	0	31 2	0 64	1 1	32 94
113-34	2086012	749539	bh01vs01		10 0	0	0	0	30	30
113-35	2086033	749569	bh03vs01		10 0	0	0	0	2 7	2 7
113-36	2086057	749563	bh04vs01		10 0	0	0 4	1 1	25	26 5
113-37	2086041	749606	bh05vs01		5 0	0	0	0	0 9	0 9
113-37	2086041	749606	bh05vs02		10 0	0	0	0	4 3	4 3
113-38	2086001	749594	bh02vs01		5 0	0	51	930	2,500	3,481
113-38	2086001	749594	bh02vs02		10 0	0	130	2,600	6,300	9,030
113-39	2086170	749587	bh11vs01		10 0	0	12	3,300	32,400	35,712
113-40	2086150	749588	bh09vs01		10 0	0	0 3	37	3,740	3,777 3
113-41	2086176	749558	bh12vs01		10 0	0	0	1 1	27	28 1
113-42	2086196	749561	bh14vs01		5 0	0	0	0	19	19
113-43	2086202	749586	bh13vs01		5 0	0	0	0	0 96	0 96
113-43	2086202	749586	bh13vs02		10 0	0	0	0	1	1
113-44	2086175	749619	bh10vs01		10 0	0	0	17	415	432

3.3 NONAQUEOUS PHASE LIQUID (NAPL)

A free phase NAPL, dark-brown in color, was observed in borehole 10191 (Phase II RFI/RI program) at a depth of approximately 4 feet and a residual NAPL was identified at approximately 6 5 to 7 feet during drilling operations Borehole 10191 was drilled to a depth of 54 feet in three days. Analytical results obtained at this depth indicated the NAPL to contain the following chemicals. 1,1,1-TCA (13,000 μg/kg or ppb), CCl_4 (28,000 μg/kg), $CHCl_3$ (8,800 μg/kg), PCE (1,300,000 μg/kg), and TCE (120,000 μg/kg).

Based on the physical properties that control the migration of NAPLs, their free phase existence in or beneath Trench T-3 is unclear It is possible that the free phase NAPL observed in borehole 10191 migrated vertically during the Phase II drilling operations or could be still trapped in Trench T-3

At borehole 24793 in the SVE Pilot Test program, two VOC samples were collected because elevated organic readings were observed in the field by the photoionization detector (PID) and the discolored soil was observed in the borehole from the 7 7- to 8-foot sampling interval The 7 7- to 8-foot core samples were described in the field to be a residual of a NAPL that discolored the soil No free phase liquids were observed for these samples. Elevated PCE (1,090,000 μg/kg) and TCE (8,100 μg/kg) were detected in these samples Upon encountering the NAPL in borehole 24793, drilling was stopped and the borehole was abandoned to prevent further contaminant migration

3.4 SOIL CHARACTERISTICS

The surface soils at OU-2 are predominantly deep, well-drained loams, clay loams, and very cobbly sandy loams with slow permeability The Rocky Flats alluvium with the OU-2 area consist predominantly of beds and lenses of poorly to moderately sorted gravels and sands A few lenses of clay and silt also occur Results of geotechnical analyses are summarized in Table 3 4-1

TABLE 3 4-1
OU-2 GEOTECHNICAL RESULTS
(ROCKY FLATS ALLUVIUM AND ARAPAHOE FORMATION)

New Site Number	Work Plan Site Number	Sample Depth (ft BGS)	Sample Strat	Moisture Content (%)	Dry Density (pcf)	Gradation			Atterberg Limits			Perm.(1) (cm/sec)	Sample Description (USCS Symbol)
						Grave (%)	Sand (%)	Silt & Clay (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic. Index (%)		
03091	30-91	43 7	Ka (No 1)	10 5	129 4	0	54	46	27	15	12	3 1E-9	Clayey Sand, Grey-Brown(SC)
03091	30-91	53 5	Ka (cs)	13 8	114 2	0	5	95	39	14	25	--	Lean Clay, Grey-Black(CL)
03591	35-91	26 5	Qrf	11 4	119 6	0	66	34	33	12	21	--	Clayey Sand, Light Red-Brown(SC)
03591	35-91	37 5	Ka (cs)	18 9	101 8	0	2	98	55	16	39	1 7E-8	Fat Clay, Grey-Brown(CH)
04491	44-91	19 8	Qrf	16 6	94 4	11	45	44	51	16	35	--	Clayey Sand, Orange-Brown(SC)
04491	44-91	26 8	Qrf	18 8	114 3	12	32	56	60	16	44	--	Sandy Fat Clay, Orange-Brown(CH)
05191	51-91	30 5	Qrf	13 3	116 5	0	50	50	40	14	26	1 9E-8	Clayey Sand, Orange-Brown(SC)
05191	51-91	48 5	Ka (cs)	15 1	110 7	0	40	60	36	15	21	--	Sandy Lean Clay, Light Grey(CL)
05191	51-91	50 5	Ka (cs)	20 6	106 9	0	11	89	42	15	27	--	Lean Clay, Grey(CL)
05291	52-91	13 3	Qrf	9 1	104 0	53	30	17	38	16	22	--	Clayey Gravel With Sand, Orange-Brown(GC)
05291	52-91	22 6	Qrf	12 5	119 2	14	56	30	47	16	31	--	Clayey Sand With Gravel, Orange-Brown(SC)
05291	52-91	29 6	Qrf	24 3	95 0	0	35	65	67	20	47	--	Sandy Fat Clay, Orange-Brown(CH)
05291	52-91	31 6	Qrf	18 4	109 4	0	49	51	40	15	25	--	Sandy Lean Clay, Orange-Brown(CL)
06191	61-91	1 6	Qrf	17 2	102 2	12	55	33	41	21	20	--	Clayey Sand, Orange(SC)
06191	61-91	10 7	Qrf	8 8	118 6	34	43	23	--	--	--	--	Clayey Sand With Gravel, Brown(SC)
06191	61-91	23 5	Qrf	5 5	114 8	48	40	12	--	--	--	--	Clayey Gravel With Sand, Orange-Brown(GC)
08591	5-91/BH419	40 7	Qrf	17 0	114 8	14	30	56	44	13	31	--	Sandy Lean Clay With Gravel, Olive-Brown(CL)
10291	BH3091	8 4	Qrf	5 2	--	51	35	14	--	--	--	--	Clayey Gravel With Sand, Orange-Brown(GC)
10291	BH3091	17 8	Ka (cs)	4 9	--	0	35	65	--	--	--	--	Sandy Lean Clay, Brown-Olive(CL)
10291	BH3091	21 8	Ka (cs)	11 5	119 5	0	50	50	30	13	17	--	Sandy Lean Clay, Grey-Brown(CL)
10291	BH3091	37 8	Ka (No 1)	10 3	121 5	0	81	19	28	11	17	3 7E-8	Clayey Sand, Orange-Grey(SC)
10291	BH3091	43 8	Ka (No 1)	14 0	115 3	0	52	48	NP	NP	NP	1 1E-8	Clayey Sand, Light Brown(SC)
10291	BH3091	47 8	Ka (No 1)	12 6	117 8	0	85	15	NP	NP	NP	--	Clayey Sand, Grey-Brown(SC)

TABLE 3 4-1
(Concluded)

10291	BH3091	51 8	Ka (No 1)	14 2	119 5	0	31	69	36	13	23	5 0E-9	Sandy Lean Clay, Brown(CL)
10291	BH3091	57 8	Ka (No 1)	12 3	121 9	0	20	80	35	18	17		Lean Clay With Sand, Grey(CL)
10391	BH3191	35 8	Ka (No 1)	17 9	111 8	0	92	8	NP	NP	NP	1 1E-4	Sand With Clay, Grey(SP-SC)
10391	BH3191	61 8	Ka (No 1)	11 2	124 5	0	51	49	29	15	14	7 3E-8	Clayey Sand, Brown(SC)
10691	BH4291	29 0	Qrf	16 2	117 1	49	33	18	--	--	--	--	Clayey Gravel With Sand, Olive-Brown(GC)
10791	BH4391	28 4	Qrf	8 8	116 6	17	55	28	--	--	--	--	Clayey Sand With Gravel, Orange-Brown(SC)
10791	BH4391	33 8	Qrf	20 3	107 5	0	47	53	49	15	34	--	Sandy Lean Clay, Brown-Olive(CL)
10791	BH4391	37 3	Qrf	12 7	118 8	10	58	32	29	13	16	--	Clayey Sand, Orange-Brown(SC)
10891	BH4491	16 7	Qrf	15 4	105 7	15	52	33	45	17	28	--	Clayey Sand, Orange-Brown(SC)
10891	BH4491	25 8	Qrf	16 3	111 3	0	58	42	40	16	24	1 2E-8	Clayey Sand, Orange-Brown(SC)
20091	NA	28 1	Qrf	10 2	124 9	0	61	39	35	14	21	1 3E-7	Clayey Sand, Brown(SC)
20091	NA	40 7	Ka (No 1)	11 9	121 4	0	45	55	29	22	7	5 4E-8	Sandy Silty Clay, Brown(CL-ML)
20091	NA	49 6	Ka (No 1)	12 3	119 1	0	53	47	24	19	5	1 5E-7	Silty Clayey Sand, Brown(SC-SM)
20791	NA	15 3	Qrf	13 1	109 1	16	65	19	38	15	23	2 2E-8	Clayey Sand With Gravel, Brown(SC)
20791	NA	20 9	Qrf	8 0	147 2	56	36	8	34	16	18	--	Gravel With Clay and Sand, Brown(GP-GC)
20991	NA	42 8	Ka (No 1)	15 1	113 7	55	41	4	NP	NP	NP	1 1E-6	Gravel With Sand, Brown(GP)
20991	NA	56 8	Ka (No 1)	13 4	117 1	0	49	51	29	14	15	6 8E-8	Sandy Lean Clay, Brown(CL)
20991	NA	60 5	Ka (No 1)	--	--	42	51	7	--	--	--	--	Sand With Clay & Gravel, Yellow-Brown(SP-SC)

Notes

BGS - Below Ground Surface
BH - Borehole
(cs) - Claystone
Qrf - Rocky Flats Alluvium
Ka - Arapahoe Formation
NA - Not Applicable
No 1 - No 1 Sandstone
NP - Non-Plastic
Perm - Permeability
Plastic Index - Plasticity Index
Sample Strat - Sample Stratigraphy

The symbol "--" indicates that the tests were not conducted on that sample

(1) Permeability tests were conducted using the fixed-wall, falling-head method at 20 degrees C

4.0 BASIS OF DESIGN FOR OFFGAS TREATMENT

The following sections detail the design criteria used in the development of the offgas treatment alternatives. These criteria include offgas treatment inlet and discharge conditions, requirements and limitations of the current SVE equipment and power supplies, regulatory requirements, and by-product generation and disposal requirements

4.1 SVE DESIGN CRITERIA FOR OFFGAS TREATMENT ALTERNATIVES

This section will define the design criteria for the existing SVE and SPSH systems These criteria will be used to develop the design criteria for the offgas treatment alternatives Additional data is currently being collected to confirm the design criteria established for the SVE system in its present configuration This additional data may affect the offgas treatment final design criteria Expanding the capability of the current SVE and offgas treatment system for higher contaminant concentrations and greater water vapor generated by SPSH requires review of the current system design and its limits

4.1.1 SVE Criteria

The existing SVE system was designed to extract soil gas from an alluvium extraction well (AV1) or a sandstone extraction well (SV1) The soil gas stream is pulled through a demister in the knockout drum to remove entrained moisture The stream then passes through high efficiency particulate air (HEPA) filters to remove dust particulates that may be contaminated with radionuclides Finally, the air stream passes through two vapor phase granular activated carbon GAC units (in series) for VOC removal The treated air stream is then discharged to the atmosphere

The SVE pilot unit is a transportable unit consisting of the following major pieces of equipment as shown on Figure 4 1-1.

- Knockout drum
- Liquid transfer pump
- HEPA filters (3)
- Blowers (2)
- GAC units (2)
- Air injection blower
- Groundwater storage tanks (2)

The design criteria for the system and each piece of equipment is summarized in Table 4 1-1

The SVE pilot unit was designed to a National Electric Code (NEC) Class I Div. II electrical classification The system is currently powered by a 125 kW transportable diesel generator Electrical requirements are 460 volts/3 phase/60 Hz

Current testing of the SVE technology will be under nine different sets of operating conditions to evaluate the system's performance and its limits Preliminary test data show the soil gas flow rate to the existing offgas treatment system averaging 11 4 cfm at 17 8% RH Other parameters are listed in Table 4 1-2 The maximum values for each parameter are the design values The soil gas stream is diluted prior to the offgas treatment Make up air averages approximately 275 scfm at an operating pressure of 140 inches of water column vacuum

Average concentrations of contaminants that have been seen in the soil gas stream (AV1) are shown on Table 4 1-3

TABLE 4.1-1

EXISTING SVE EQUIPMENT DESIGN CRITERIA

	Average	Maximum
System Airflow Rate	300 scfm @ 10 in Hg vacuum	600 scfm @ 0 to 2 in Hg vacuum
System Pressure/Vacuum	5 to 8 in Hg vacuum	10 in Hg vacuum
System Temperature	50°F (inlet) 140°F (discharge)	300°F
Blower B300	300 scfm	600 scfm 15 in Hg vacuum 100°F temp rise
Blower B500	300 scfm	500 scfm 18 in Hg vacuum 60°F temp rise
HEPA filters		
FL-200		500 scfm
FL-210		125 scfm
FL-220		500 scfm
		10 in Hg operating vacuum
Knockout Drum	100 gal	150 gal 650 scfm Full vacuum rating

TABLE 4.1-2

PILOT TEST SITE NO. 1 INLET CONDITIONS OF EXTRACTED SOIL GAS AND MAKE UP AIR

Parameter	Minimum	Maximum	Average
Pressure (in Hg vacuum)[1]	2	10	9 8
Soil Gas Flow Rate (scfm)	4	100	11 4
Soil Gas Relative Humidity (%)	5	100	17 8
Soil Gas Temperature (°F)	30	60	43 0
Makeup Air Flow Rate (scfm)	200	500	275
Makeup Air Relative Humidity (%)	8	100	10
Makeup Air Temperature (°F)	-10	110	60
Combined Flowrate (scfm)	300	600	310

[1] The values for pressure measure the pressure drop, in inches of mercury, below one atmosphere, or 29 9 in Hg

TABLE 4.1-3

AVERAGE VOC CONCENTRATIONS FROM COMPLETED PILOT TEST DATA

	AV1 (ppmv/v)	Make Up Air (ppmv/v)	Blower 300 (ppmv)
Analyte	Average Concentration[1]		
CCl_4	560	0 0009	29 3
PCE	750	0.111	37 3
Total VOCs	1,400	0 117	70 6

[1] Based on currently unvalidated raw data from Pilot Test No 1, run 2-3

The system was designed to use two blowers in series The blowers are located upstream and downstream from the GAC units Recent pilot test data (Table 4 1-4) have shown the discharge pressure and temperature from the first blower (B300) to be 5 to 7 in Hg vacuum and 90 to 120°F Discharge conditions from the exhaust blower (B500) are 0 1 to 0 3 psig and 125 to 150°F The discharge air flowrate from the system has been 300 to 350 scfm

The current offgas treatment method is a vapor phase GAC system (D-400, D-410) The carbon steel vessels are four feet in diameter, approximately 7.5 feet tall, with a lined interior for corrosion protection The vessels are ASME code stamped and rated for full vacuum Basic design limits on the vessels are as follows in Table 4 1-5 Each column contains approximately 1,800 pounds of coconut based activated carbon (Westates VACarb or equivalent) Specifications for the carbon are also found in Table 4 1-5

Table 4 1-6 shows maximum concentrations of each of the most prevalent VOCs and the corresponding removal rates for the contaminants

The existing SVE and GAC system described above has the following limitations. the maximum system flow rate and pressure are approximately 300 scfm at 10 in Hg vacuum The existing HEPA filters are rated at 10 in Hg vacuum maximum and would have to be replaced to achieve a higher vacuum operating pressure. The blowers are capable of 600 and 500 scfm maximum at low vacuum operating pressure (0 to 2 in Hg vacuum) The knockout drum has a limited capacity of 150 gallons.

4.1.2 SPSH Criteria

The SPSH will be tested at the same location as the Pilot Test Site No 1, Trench T-3 (IHSS 110) The test will be comprised of three main testing periods.

TABLE 4.1-4

OPERATING CONDITIONS FROM COMPLETED PILOT TEST DATA

Location	P (in Hg)	ΔP (in Hg)	T (°F)	ΔT (°F)	RH (%)	Δ RH (%)	F (scfm)
Extraction Well (110)	-9 79	NA	23 8	NA	58 6	NA	11 43
Make Up Air (100)	-9 72	NA	24 0	NA	56 9	NA	272 86
Before HEPA Filter (200)	-10.58	-0 86	25 5	5 5	39 4	17 5	--
After HEPA Filter (201)	-10 83	-0 25	--	NA	--	NA	--
After Blower 300 (300)	-5.57	+5 26	101 5	76	3 13	36 3	--
After GAC 1 (400)	-3 79	+1 78	102[2]	0 5	--	NA	--
After GAC 2 (410)	-4 21	-0 42	86 3[2]	15 7	--	NA	--
After Blower 500 (500)	+.03	+4 24	138 3	52	--	NA	310 86

P = Pressure
ΔP = Pressure Change
T = Temperature
ΔT = Temperature Change
RH = Relative Humidity
ΔRH = Relative Humidity Change
F = Flow Rate

[1] Based on data from Pilot Test Nos 2-3 and 3-2
[2] Temperature measured in GAC unit prior to discharge

TABLE 4.1-5

EXISTING GAC DESIGN CRITERIA

Air Flow Rate	300 scfm (average)	600 scfm (max)
Temperature	70°F (average)	200°F (max)
Pressure	8" Hg (average)	10" Hg (max)
Pressure drop across units	--	1.5 psi (max)
Carbon Media Parameters:		
Size (U S Sieve)	4 x 8	
Type	Coconut Shell	
Hardness no (min , wt %)	97	
Ash (max , wt %)	2	
Moisture (max. as packaged, wt %)	2	
CCl_4 Activity (Min.)	62%	
Iodine No. (Min.)	1,000	
Retentivity (wt %)	40	
Surface area (B.E.T)	1250 m^2/g	
Pore Volume	0 55 cc/g	
Mean particle diameter	3 4 mm	
Apparent density	29 $lb./ft^3$	

TABLE 4.1-6

ESTIMATED VOC REMOVAL RATES

PILOT TEST NO	AVERAGE VOC CONCENTRATION (ppmv)	AVERAGE VOC CONCENTRATION (ug/l)	AVERAGE FLOW RATE (scfm)	AVERAGE VOC REMOVAL FLOW RATE (lbs/hr)	HOURS OF OPERATION	LBS OF VOC REMOVED
1	1600	10872	6	0 24	4	1
2	1950	13250	13	0 64	55	35
3	700	4757	1	0 02	48	1
4	700	4757	7	0 12	48	6
5	1950	13250	16	0 79	16	13
6	2100	14270	18	0 96	16	15
7	800	5436	9	0 18	16	3
8	2100	14270	20	1 07	16	17
9	800	5436	11	0 22	16	4
					TOTAL LBS VOCS =	95

Baseline SVE Test Without Soil Heating

This test will be conducted over a few weeks to provide data on VOC concentrations in the extracted soil gas without heating. This data will be used to compare with the VOC concentrations in the extracted soil gas seen during heating as an indication of SPSH effectiveness The requirements for the offgas treatment unit for this segment of the test will be similar to those for Pilot Test Site No 1

Six Phase Soil Heating

The heating part of this test will be run for approximately 45 days Electrical power will be applied to the soil for heating during this time Soil temperatures will increase to the boiling point of water over an estimated 10 day heat-up period During this time, steam will be generated and extracted from the subsurface The design conditions for this period are listed in Table 4 1-7 under the "Typical" operation column When the bulk soil temperature has reached the boiling point of water, the extracted gas stream from the subsurface is expected to have a high water vapor content The design conditions for this case are listed in Table 4 1-7 under the "Maximum Steaming" column

Cool-Down

After the soil heating has been discontinued, the subsurface soil will go through a cool-down period, lasting approximately 2 months During this time, the offgas treatment unit will continue operation The design conditions for this case are listed in Table 4 1-7 under the "Typical" operation column

Power requirements for the SPSH are approximately 300 to 500 kW Additional power will be required for the offgas treatment system

TABLE 4.1-7

DESIGN CRITERIA FOR SPSH

	Typical	Maximum Steaming
Total flowrate (scfm)	300	500
Air flowrate (scfm)	150	50
Water vapor flowrate (scfm, gpm)	150 (0 8)	450 (2 5)
Temperature (°F)	150	212
Pressure (inches Hg vacuum)	15	15
VOC concentration (ppmv) (in combined air and steam)	6,500	20,000
VOC removal rate (lbs/hr)	20 - 30	260
Total volume water generated (gallons)	45,000	45,000

4.1.3 SVE, SPSH, and Offgas Treatment Waste By-products

During normal operation of the SVE, SPSH, and offgas treatment systems, by-products will be generated The SPSH will be generating a large quantity of steam during operation The steam production rate for SPSH is based on both an energy balance and experimental field data If all of the power is assumed to be devoted to boiling water (i e , the soil and water have been heated up to 100°C and there are no heat losses), a steam/condensate production rate of 3.5 gpm could be attained The first step in the soil vapor extraction process will be to condense the steam from the soil gas stream This condensate will require storage and potential treatment prior to disposal Accounting for heat losses, the maximum flow is anticipated to be 2 5 to 3 gpm A total of approximately 45,000 gallons of condensate is estimated to be produced

The condensate will contain varying amounts of VOCs, depending on the offgas treatment option selected, and may require treatment prior to discharge The options for treatment and disposal of this condensate (45,000 gallons) include the following existing treatment units at RFP.

- 881 Hillside water treatment unit (ultraviolet [UV] oxidation and ion exchange), which has a treatment capacity of 30 gpm,
- OU-2 Field Treatment Unit (precipitation, membrane filtration,and GAC), which has a treatment capacity of 60 gpm,

Both of these options are existing treatment units with limited capacity and capabilities

A new treatment unit will be required if the existing treatment units are not available or capable of processing the condensate The evaluation of the existing treatment systems will be completed as part of the detailed design of the offgas treatment system Discharge options for treated condensate that include reuse as make-up for the scrubber, discharge to South Walnut Creek and discharge to the RFP Sewage treatment plant will also be evaluated

in the detailed design phase Typical options for treating the condensate would be liquid phase GAC, UV oxidation, or air stripping. Air stripping is estimated to be the most cost effective alternative The condensate would be pumped from a storage tank to an air stripper system The air stripper system would consist of a tower with packing and sump, a blower, instrumentation and controls, and a pump The exhaust gas containing VOCs from the air stripper would be discharged directly to the atmosphere or into the inlet gas stream of the offgas treatment system

Other waste by-products of the existing SVE and GAC system include the used HEPA filters and the spent GAC Used HEPA filters will be disposed in the RFP Landfill if no radioactivity is detected Should radioactivity be detected, the used HEPA filters would be stored in a drum on site until their disposition has been determined It is assumed that HEPA filters will be part of the system used for the SPSH pilot test as well as additional pilot tests Therefore, HEPA filters will be a waste by-product of all pilot tests The spent GAC would be removed from the vessels and stored in drums on site The spent GAC, depending on its chemical profile, could be sent off site for regeneration Other potential options include off-site disposal as a hazardous waste or on-site regeneration

Some of the offgas treatment systems generate hydrogen chloride (HCl) as a product of destruction The offgas is scrubbed with caustic solution to neutralize the acid prior to discharge This further treatment produces a spent caustic solution which may require treatment prior to disposal or storage. An option for treatment and disposal of the spent caustic solution would be the 374 Evaporator Facility at RFP This facility consists of a three stage chemical treatment and a four stage evaporator The system has a capacity of 34 gpm, but is not designed to accept organic materials above detection limit The destructive technologies requiring acid gas scrubbing have DREs of 99 percent or greater, so no detectable organic compounds are expected

4.1.4 Other Criteria

In addition to the above design criteria, several other general criteria are important to the selection and design of the offgas treatment system. The future system should be portable to enable the complete treatment system to be moved to another site at RFP The treatment unit should have the flexibility to expand its capacity for future projects with increased treatment requirements The system should be capable of performing under future long-term operations The future offgas treatment should incorporate the existing SVE system and be amenable to retrofitting the existing system. The system should be self-contained and require minimal utility hookups from the RFP site.

4.2 REGULATORY REQUIREMENTS

The following sections describe the regulatory requirements that may be applicable to the existing SVE system and potential offgas treatment alternatives used for the pilot tests. Since this is a Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) site, Federal and State regulations may be potentially applicable to the offgas treatment systems being evaluated. Therefore, Resource Conservation and Recovery Act (RCRA) and State air emission regulations were reviewed for their applicability to the treatment alternatives RCRA regulates the management, storage, treatment, and disposal of hazardous wastes State air emission regulations regulate hazardous air pollutants (HAPs)

4.2.1 Air Emission Requirements

Remediation of organic contaminated soils by the SVE technology can result in the release of VOC emissions to the atmosphere The VOCs of concern for the Pilot Test Sites No 1 and No 2 are tetrachloroethylene (PCE), carbon tetrachloride (CCl_4), 1,1-dichloroethane (1,1-DCA), and trichloroethylene (TCE) These compounds are listed as HAPs under the regulations of the CDH

The regulatory requirements for the emission of these potential pollutants have been reviewed and are summarized below. Depending on estimated emission rates, these requirements could include initial reporting to the CDH by submitting an Air Pollution Emission Notice (APEN) If the annual emission rate for each constituent is below the applicable reporting level, then an APEN is not required for that particular HAP. As defined by the CDH in Regulation 3 (August 30, 1993), the contaminants of concern for the Pilot Test Sites No 1 and No 2 are categorized as HAPs and are assigned to Bins as defined by the CDH which include Bin A (PCE and CCl_4), Bin B (1,1-DCA), and Bin C (TCE) The level at which emissions from the offgas treatment system would require reporting (submittal of a CDH APEN for each Bin) are:

- Bin A - 250 lbs/yr
- Bin B - 2500 lbs/yr
- Bin C - 5000 lbs/yr

These reporting thresholds are based on uncontrolled emissions The reporting threshold for VOCs is one ton per year. Table 4 2-1 provides a comparison of the average VOC emission rate from the SVE system without offgas treatment to the maximum APEN reporting rate

Several offgas treatment technologies combust or oxidize the VOCs and produce CO_2, water, and HCl in the exhaust gas. HCl is also listed in the CDH regulations as a HAP and falls into Bin A.

In general, the VOCs and HCl are categorized as HAPs and have levels that trigger reporting, but at this time have no emission standards that must be achieved Therefore, only reasonably available control technology (RACT) can be applied (see CDH Regulation No 7) RACT allows the removal efficiency of the offgas treatment system to be one that is commonly achieved by similar equipment used in other applications For the purpose of this evaluation of offgas treatment alternatives, RACT will apply and a removal efficiency of 95 percent or greater will be the criteria

TABLE 4.2-1

COMPARISON OF EMISSION RATES TO CDH AIR POLLUTANT EMISSION NOTICE (APEN) CRITERIA

Contaminant	Average Emission Rate without Offgas Treatment (lbs/hr)	Average Emission Annual Rate without Offgas Treatment (lbs/yr)*	Max APEN Reporting Emission Rate (lbs/yr)
Bin A			
PCE	20 51	44,301 60	250
CCl_4	16 11	34,797 60	250
Bin B			
1,1 DCA	0 89	1,919 25	2,500
Bin C			
TCE	0.21	449 18	5,000

* Operating Scenario: 3 months (2,160 hours), 24 hours per day, 30 days per month

Pilot Test No. 2 is not expected to last more than 3 months

In addition to VOCs and HCl, some offgas treatment technologies and associated equipment produce nitrogen oxide (NO_x), a criteria pollutant NO_x emissions of 250 tons per year (tpy) designate a major source

Potential plantwide NO_x emissions at RFP are approximately 225 tons per year Thus, RFP is considered a minor source with respect to Prevention of Significant Deterioration (PSD) regulations However, NO_x is also a precursor to PM-10. Since RFP is located in the Denver PM-10 nonattainment area, any sources of NO_x would have to be viewed with respect to the nonattainment permitting requirements for major sources in a PM-10 nonattainment area The major source threshold in a nonattainment area is 100 tons per year The APEN reporting threshold for NO_X is 1 ton per year

4.2.2 RCRA Requirements

RCRA regulates the management, storage, treatment, and disposal of hazardous waste Hazardous waste is a subset of solid waste Solid waste is defined by the RCRA statute as "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material including solid, liquid, semisolid, or contained gaseous material. " While uncontained gases are not regulated by RCRA, it is EPA's policy that offgases from the treatment of hazardous waste are regulated under RCRA under the derived-from rule Thermal treatment units, depending on the type of unit and how it operates, can be regulated under RCRA The Code of Federal Regulations (CFR), Section 40, Part 264 contains the standards for regulated units 40 CFR Part 266 contains standards for recycling units Boilers and industrial furnaces are regulated under Part 266, Subpart H Part 264, Subpart O contains the incinerator standards Other types of thermal treatment units that do not qualify as either incinerators or boilers/industrial furnaces could be regulated as miscellaneous units under Part 264, Subpart X

After review of Parts 264 and 266, it appears that thermal oxidation technology could be considered an incinerator under RCRA and subject to the performance standards The other

options, flameless thermal destruction, catalytic oxidation, and high energy corona could be considered miscellaneous units

The incinerator standards in 40 CFR Part 264 Subpart O contain a section on performance standards (Section 264 343) For hazardous waste (except dioxin wastes), the incinerator must meet a destruction and removal efficiency (DRE) of 99 99 percent for each principal organic hazardous constituent The miscellaneous unit standards have a general environmental performance standard in Section 264 601 This standard does not have specific DRE requirements but does, however, allow the requirements of Part 264, including Subpart O, to be applied if they are appropriate for the miscellaneous unit being permitted

RCRA does regulate air emissions from process vents (40 CFR Part 264, Subpart AA) and equipment leaks (40 CFR Part 264, Subpart BB) at RCRA treatment, storage, disposal (TSD) facilities The process vent standards apply to process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, or air or steam stripping operations that manage hazardous waste with organic concentrations of at least 10 ppmv/v if these operations are conducted in units that are subject to RCRA permitting or hazardous waste recycling units Closed-vent systems and control devices used to comply with the provisions of Subpart AA are regulated at 264 1033 Enclosed control devices (e g , a vapor incinerator, boiler, or process heater) must reduce organic emissions vented to it by 95 weight percent or greater, achieve a total organic compound concentration of 20 ppmv/v, or provide a minimum residence time of 0 50 seconds at a minimum temperature of 1400°F

It appears that RCRA may have applicability to some of the offgas treatment alternatives but to what degree would require a determination by the CDH RCRA division

For the purpose of this evaluation of offgas treatment alternatives, it is assumed that the organic emissions should be reduced by 95 percent as stated above This would be in agreement with the State requirement of RACT which has been estimated to be approximately 95 percent removal

5.0 TECHNOLOGY IDENTIFICATION AND SCREENING

This section presents the potentially applicable technologies for treatment of VOCs in a gas stream Each technology will be reviewed and discussed in general terms. The technologies will undergo a preliminary screening with respect to effectiveness and implementability. The technologies that pass the preliminary screening will be used to develop alternatives for the removal of VOCs from extracted soil gas

5.1 TECHNOLOGY IDENTIFICATION AND SCREENING CRITERIA

Table 5 1-1 presents the list of potentially applicable technologies for treatment of VOCs in air streams These technologies are discussed in the following sections.

TABLE 5.1-1

POTENTIALLY APPLICABLE TECHNOLOGIES

Granular Activated Carbon	Ozone-UV-Granular Activated Carbon
- Offsite Regeneration	Adsorption/Condensation (Purus)
- Offsite Disposal	Condensation/Refrigeration
- Onsite Regeneration	Flameless Thermal Oxidation
Membrane Separation	Thermal Oxidation
Biofiltration	Catalytic Oxidation
Chemical Reduction	High Energy Corona
Photo-dehalogenation	

The technologies were screened with respect to two major criteria effectiveness and implementability. These criteria were defined as follows

Effectiveness

Removal Efficiency - How effective is the technology at removing the contaminants of concern?

Implementability

1 Is the technology compatible with the existing SVE unit to minimize modifications to the process system?
2 Technology maturity for specific contaminant - At what level of development is the technology (e.g , emerging, commercially available, etc)?
3 Operations - What items are necessary for operation and maintenance of the technology (e g., incineration requires combustion fuel)?
4 Adverse impacts - If the technology is implemented, what wastes will be generated and can the waste be treated and/or disposed of easily?

5.2 TECHNOLOGY DESCRIPTION AND PRELIMINARY SCREENING

5.2.1 Granular Activated Carbon (GAC)

The GAC technology is presently used for offgas treatment with the existing SVE pilot test unit. GAC media remove vapor-phase VOCs from gas streams by adsorption The gas stream is passed through a packed column(s) of GAC media and the treated gas is discharged to the atmosphere. The VOC loading rates for the GAC media vary depending on the vapor phase constituents and their inlet concentrations Once the GAC media are saturated and VOC breakthrough occurs, the GAC media are replaced The media are typically regenerated or disposed of off site Regenerated media can subsequently be reused as treatment media However, VOC loading capacities for the regenerated GAC media are reduced through continued regeneration and recycling

Effectiveness

GAC has been proven to be very effective at removing VOCs from gas streams, with removal efficiencies of greater than 99 percent However, high concentrations and flow rates can quickly saturate the GAC media

Implementability

The high water content in the inlet gas stream expected with SPSH will require a condenser upstream of the GAC units The condensate removed from the soil gas stream may require further treatment prior to disposal The GAC technology will require offsite regeneration' or disposal of spent carbon. Presently, the maximum operating inlet concentration to the GAC units is 5,000 ppmv/v, and shut-down occurs when concentrations exceed 10,000 ppmv/v Higher concentrations of VOCs anticipated during SPSH would use more carbon, thereby generating larger quantities of spent carbon

5.2.2 Membrane Separation

The membrane separation process is based on condensation and selective membrane permeability to VOCs versus oxygen, nitrogen, and other gases The extracted gas is first compressed to 150 psig and then cooled to approximately 35°F in a refrigerant cooled heat exchanger Condensate is collected and removed The uncondensed stream then enters the membrane unit and is separated into a VOC rich stream and a VOC depleted stream The VOC rich stream is routed back to the soil gas stream prior to the compressor The VOC depleted stream is then passed through GAC to remove the remaining VOCs The membrane separation technology alone could achieve a 95 percent removal efficiency for VOCs GAC treatment would be added for increased VOC removal

Effectiveness

This technology alone does have the potential to meet the minimum 95 percent removal efficiency GAC polishing would have to be added to the treatment train to obtain a greater than 95 percent removal efficiency for VOCs

Implementability

Membrane separation is commercially available and could be incorporated into the SVE unit at OU-2 Therefore, this technology will be retained for further consideration

5.2.3 Biofiltration

Biofiltration was developed for the removal of organics from gas streams The air stream passes through activated carbon media and adsorbs the VOCs Microbes on the activated carbon media biologically reduce the VOCs to water and carbon dioxide. Biofiltration has not been demonstrated to process halogenated VOCs.

Effectiveness

This technology is not applicable to the contaminants of concern in the OU-2 air stream On this basis, this technology will not be retained for consideration as part of a remedial action alternative.

5.2.4 Chemical Reduction

A gas-phase thermo-chemical reduction reaction of hydrogen with chlorinated organic compounds at elevated temperatures produces lighter, smaller hydrocarbons The products are primarily HCl, hydrogen and methane The reaction is enhanced by the presence of water The waste stream is preheated to 300°F and then transferred to the reactor where it

is heated to approximately 1650°F The stream then passes through a scrubber where the HCl, heat, particulates, and water are removed Ninety-five percent of the scrubber stream (primarily hydrogen and methane) is circulated back to the reactor The remaining 5 percent is used for fuel for preheating the waste Chemical reduction can not process streams containing oxygen

Effectiveness

This technology is not effective for treatment of air streams containing oxygen Therefore, chemical reduction will not be retained for further consideration

5.2.5 Photo-dehalogenation

The process converts volatile halogenated compounds to less halogenated compounds or fully dehalogenated compounds by initiating reactions in a reducing atmosphere with ultraviolet light The process inputs are hydrogen or natural gas, heat, and ultraviolet light The primary products are dehalogenated organics and HCl Therefore, a caustic scrubber will be needed to remove the HCl prior to venting, and a secondary treatment will be needed to process the dehalogenated volatiles

Effectiveness

This technology is applicable for reducing the VOCs in the OU-2 air stream, although secondary VOC treatment would be required The technology is emerging, so removal efficiencies are unknown

Implementability

Equipment for this technology is not readily available

Based on both effectiveness and implementability, this technology will not be retained

5.2.6 Ozone-UV-Granular Activated Carbon (GAC)

The ozone-UV-GAC system is comprised of three unit processes, including a gas phase photolytic reactor chamber, a mist air dispersion reactor/scrubber (aqua reactor), and two GAC adsorption beds The airstream first enters the photolytic reaction chamber, where the VOCs are oxidized in the presence of activated oxygen (ozone, etc) and ultraviolet light The mist air dispersion reactor/scrubber maintains a uniform (100%) relative humidity level The contaminants are further oxidized via reaction with activated oxygen in the reactor and HCl and other non-carbonaceous chlorine species generated AS by-products of the reactions with chlorinated organic compounds in the photolytic and aqua reactors are scrubbed out of the gas stream The scrubbing solution is continuously recycled Finally, the gas stream passes through the GAC bed which adsorbs the remaining chlorinated organics. The water vapor in the gas stream quenches exothermic adsorption reactions involving PCE, CCl_4, or ozone Dual GAC units are cyclically operated in parallel, with one operating in adsorption mode while the other operates in regeneration mode The GAC beds undergo daily regeneration by employing activated oxygen at ambient temperatures in a process that desorbs and destroys the captured contaminants This gas stream from the regenerating GAC unit is cycled back into the photolytic reactor inlet and reprocessed. With the proper selection of methods for generating activated oxygen and the proper selection of ultraviolet light frequency, no hindrances have been observed in destroying CCl_4 or other chlorinated organic compounds

Effectiveness

This technology, with a destruction removal efficiency (DRE) of 95 to 99 percent, is effective in treating the contaminants of concern in the OU-2 air stream

Implementability

Although this is a proprietary technology through a single vendor, it is commercially available and compatible with the existing SVE unit To support the system, an activated oxygen generator is required Caustic will be required to neutralize the HCl that results from chlorinated organics destruction This will generate a spent caustic waste stream

This technology will be retained for further consideration

5.2.7 Adsorption/Condensation (Purus)

This process is based upon VOC adsorption, bed regeneration, and VOC condensation and collection The gas stream is passed through a packed bed of proprietary synthetic resin which removes VOCs Once the bed is loaded, the offgas is diverted to a fresh bed The loaded bed is regenerated by heating and flushing with nitrogen The VOCs are then condensed and transferred to a storage tank from the flush gas VOC removal is greater than 99 percent.

Effectiveness

This technology provides a greater than 99 percent removal efficiency for the contaminants of concern in the OU-2 air stream

Implementability

The equipment is compatible with the existing SVE unit and readily available The system requires nitrogen gas and an upstream condenser, and waste streams would include the condensed water and the recovered VOCs

Therefore, this technology will be retained for consideration.

5.2.8 Condensation/Refrigeration

The stream is passed through series of heat exchanger(s) to cool the gas and condense water and VOCs from the extracted soil gas stream The cooling process can be accomplished in several steps and can use a combination of air heat exchangers, water heat exchangers, and refrigeration units. The treated stream will require a secondary treatment to remove the residual VOCs (e g , GAC, catalytic oxidation, etc)

Effectiveness

This technology is applicable for treatment of the contaminants of concern in the OU-2 air stream, although the addition of polishing GAC would be required to achieve the required cleanup goal.

Implementability

This technology is compatible with the existing SVE unit and, specifically, could use the existing GAC units for exhaust gas polishing This is an established, commercially available technology which requires only electrical power for operation Waste streams would include water condensate, recovered VOCs, and possibly spent GAC media

This technology will be retained for further consideration

5.2.9 Flameless Thermal Oxidation

Flameless thermal destruction uses a packed bed thermal oxidizer operating at 1600°F to 2000°F An inert ceramic matrix is used as the packing material to enhance fume mixing and also provide thermal inertia A DRE of greater than 99 percent with negligible NO_x and CO production is achievable An enthalpy content of the gas greater than 30 British Thermal Units per standard cubic feet (BTU/scf) will be self-sustaining once operating conditions are met (i e , no supplemental fuel is required) Prior to operations, the packing material is preheated by a combustion system or electric heaters. The process is currently used for fugitive VOC emission and process offgas abatement Because the SVE offgas contains chlorinated organics, hydrogen chloride (HCl) will be produced and a caustic scrubber will be necessary to remove and neutralize the HCl prior to discharging the offgas to the atmosphere

Effectiveness

This technology has a greater than 99 percent removal efficiency for the OU-2 air stream contaminants of concern

Implementability

Although caustic scrubbing is required, this technology is available and compatible with the existing SVE unit Additionally, an upstream condenser will be required to remove water from the offgas stream, which will reduce power requirements in the oxidizer as well Waste streams will include the water condensate and spent caustic from the scrubber

This technology will be retained for further consideration

5.2.10 Thermal Oxidation

Thermal oxidation destroys the VOCs by oxidizing the gas stream at temperatures of 1600°F to 2000°F with a residence time of approximately 2 seconds The oxidation system requires supplemental fuel to increase the gas temperature for treatment HCl gas is produced, requiring removal and neutralization prior to discharge to the atmosphere

Effectiveness

This technology has a greater than 99 percent removal efficiency for the OU-2 air stream contaminants of concern.

Implementability

Although caustic scrubbing is required, this technology is available and compatible with the existing SVE unit Additionally, an upstream condenser will be required to remove water from the offgas stream, which will reduce power requirements in the oxidizer as well Waste streams will include the water condensate and spent caustic from the scrubber

This technology will be retained for further consideration

5.2.11 Catalytic Oxidation

Catalytic oxidation is a process by which VOCs are oxidized in the presence of a catalyst The offgas is heated to approximately 700°F and passed over a catalyst where it is oxidized to carbon dioxide, water, and HCl. High contaminant loading rates may cause heat build-up within the catalyst However, if the contaminant loading rate is known, the system can be designed to alleviate the heat build-up. The process is continuous and can be implemented either as a once-through process or using recuperative heat exchange to lower operating costs Conversion efficiencies are determined in the design phase and can range from 95 to

greater than 99 percent removal of contaminants depending on residence time and the specific catalyst

Effectiveness

This technology has a greater than 99 percent removal efficiency for the OU-2 air stream contaminants of concern

Implementability

Although this technology requires a fuel source for combustion and a caustic scrubber, it is compatible with the existing SVE unit and commercially available An upstream condenser will be required to remove entrained water Waste streams will include the condensate as well as spent caustic from the scrubber

This technology will be retained for further consideration

5.2.12 High Energy Corona

A high voltage electric field is established across a packed bed of dielectric pellets to produce a low-temperature (near ambient temperature) plasma that destroys organics (Battelle 1993) Because treatment occurs at low temperatures, high energy corona is not an incineration process, but is instead classified as an advanced oxidation process (AOP), along with UV oxidation and ozonation among others In pilot tests of the high energy corona system, 99 percent destruction of TCE occurred at a residence time of 1 2 seconds while 99 percent PCE destruction occurred at 3 3 seconds Further tests with different dielectric pellet materials have demonstrated increased destruction rates The system may require inlet humidities to be maintained above 15 percent RH to minimize static charge accumulation and sparking At higher humidities (90 percent RH and above), longer residence times are required to avoid the formation of significant levels (e g , 5 ppmv/v carbon tetrachloride)

of by-products. Because the SVE offgas contains chlorinated organics, HCl will be produced and a caustic scrubber will be necessary The concentration of NO_x in the offgas is approximately 1 ppmv/v

Effectiveness

This technology is applicable to the OU-2 air stream contaminants of concern Although this is an emerging technology, the expected destruction efficiency is greater than 99 percent for both chlorinated and non-chlorinated compounds

Implementability

This technology has been pilot tested with an SVE unit and is compatible with the existing SVE unit The high energy corona reactors are modular, and the system can be expanded for minimal cost The oxidizer system requires approximately 14 kW of power Tests have been successfully completed with inlet concentrations of 2,500 ppmv/v and 100 percent relative humidity but only at a bench or pilot scale level This technology will require an upstream condenser to remove moisture and a downstream scrubber to remove HCl produced by the high energy corona Waste streams will include HEPA filters, the condensate, and the spent caustic.

Since this technology is emerging, it will not be retained for further consideration

5.3 RETAINED TECHNOLOGIES

Table 5 3-1 presents the list of potentially applicable technologies for treating the OU-2 SVE offgas Evaluation comments regarding the effectiveness and implementability of the technologies are presented, and each technology is characterized as either retained or not retained for further evaluation The following technologies will be retained for consideration as part of remedial action alternatives

TABLE 5.3-1
PRELIMINARY TECHNOLOGY SCREENING

Technology	Effectiveness			Implementability				
	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O&M Requirements	Compatibility	Adverse Impacts	Retain Yes/No
GAC with off-site regeneration or disposal	Applicable to contaminants of concern More applicable to low loading rates	Greater than 99 percent	Yes May require large quantities of GAC because of high loading rates	Commercially available	Remove and replace spent GAC Will require upstream condenser, and subsequent water treatment	Currently in the SVE treatment train Impractical because of anticipated high loadings	Spent GAC Automatic shut-off for VOC concentrations exceeding 10,000 ppmv	Yes
Membrane Separation	Applicable to chlorinated and non-chlorinated volatile organics	95 percent removal (GAC polishing would improve the removal efficiency)	Yes, with GAC polish	Commercially available	Large power supply for the compressor, vacuum pumps, and refrigeration	Equipment available Compatible with the SVE unit	GAC polishing required, A VOC contaminated aqueous phase and potentially an organic liquid phase	Yes
Biofiltration	Cannot process contaminants of concern	N/A	No	N/A	N/A	N/A	N/A	No
Chemical Reduction	Cannot be used to process streams with oxygen	N/A	N/A	N/A	N/A	N/A	N/A	No

TABLE 5.3-1
PRELIMINARY TECHNOLOGY SCREENING

Technology	Effectiveness			Implementability				
	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O&M Requirements	Compatibility	Adverse Impacts	Retain Yes/No
Photo-Dehalogenation	Dehalogenated contaminants of concern, but VOCs are produced	Unknown	Unknown	Emerging	Requires H_2 gas or natural gas	Equipment not commercially available	Requires further VOC treatment and scrubbing for HCl A secondary treatment would be required to treat the dehalogenated VOCs	No
Ozone-UV-GAC	Applicable to chlorinated and non-chlorinated volatile organics	Greater than 95 percent removal	Yes	Commercially available	Power Will require upstream cooler	Equipment available Compatible with the SVE unit	Caustic scrubbing required	Yes
Adsorption/ Condensation (Purus)	Applicable to contaminants of concern	Greater than 99 percent removal	Yes	Commercially available	Requires electrical power Will require an upstream condenser	Equipment available. Technology compatible with the SVE unit	A VOC contaminated aqueous phase and potentially an organic liquid phase	Yes

TABLE 5.3-1

PRELIMINARY TECHNOLOGY SCREENING

Technology	Effectiveness			Implementability				
	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O&M Requirements	Compatibility	Adverse Impacts	Retain Yes/No
Condensation/ Refrigeration	Applicable to contaminants of concern	Greater than 99 percent with GAC polishing	Yes with GAC polishing	Commercially available	Requires electric power	Equipment commercially available Compatible with the SVE unit	GAC polishing required, A VOC contaminated aqueous phase and potentially an organic liquid phase	Yes
Flameless Thermal Oxidation	Applicable to chlorinated and non-chlorinated VOCs	Greater than 99 percent destruction	Yes	Commercially available	Supplemental fuel Will require an upstream condenser	Equipment Available Technology is compatible with the SVE unit as configured	Caustic scrubbing required	Yes
Thermal Oxidation	Applicable to chlorinated and non-chlorinated volatile organics	Greater than 99 percent destruction	Yes	Commercially available	Requires a large volume of combustion fuel Will require an upstream condenser	Equipment available Technology is compatible with the SVE unit as configured	Caustic scrubbing required	Yes

TABLE 5.3-1
PRELIMINARY TECHNOLOGY SCREENING

Technology	Effectiveness			Implementability				
	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O&M Requirements	Compatibility	Adverse Impacts	Retain Yes/No
Catalytic Oxidation	Applicable to chlorinated and non-chlorinated VOCs	Greater than 99 percent destruction	Yes	Commercially available	Requires a moderate volume of combustion fuel Will require an upstream condenser	Equipment available Technology is compatible with the SVE unit as configured	Caustic scrubbing required Maximum inlet concentration (with no dilution) of 5,000 ppmv	Yes
High Energy Corona	Applicable to chlorinated and non-chlorinated VOCs	Greater than 99 percent PCE Destruction	Yes	Emerging	Power required Will require an upstream condenser	Full-scale systems have not been constructed or tested A pilot system was designed and tested with an SVE system.	Caustic scrubbing required	No

- GAC
- Membrane Separation
- Ozone-UV-GAC
- Adsorption/Condensation (Purus)
- Condensation/Refrigeration
- Flameless Thermal Oxidation
- Thermal Oxidation
- Catalytic Oxidation

6.0 DEVELOPMENT AND EVALUATION OF ALTERNATIVES

This section develops each of the retained technologies into alternatives and describes how each of these technologies would be incorporated with the existing SVE pilot unit The development of alternatives includes identifying assumptions for design capacity, installation, and operations These alternatives are then evaluated with respect to effectiveness, implementability and cost, and a comparison of alternatives is performed Advantages and disadvantages for integration with the SVE unit are also described The following alternatives are identified for providing offgas treatment for the existing SVE Pilot Unit and the SPSH

- Existing GAC treatment with offsite regeneration or disposal
- Membrane separation
- Ozone - UV - GAC
- Adsorption/Condensation (Purus)
- Condensation/Refrigeration
- Flameless thermal oxidization
- Thermal oxidation
- Catalytic oxidation

6.1 SUMMARY OF DESIGN CRITERIA

The design criteria for the SVE and SPSH systems have been discussed in detail in Section 4 0 The design criteria used in developing the offgas treatment alternatives are summarized in Table 4 1-7 The SPSH system requirements that have the most impact on the offgas treatment design criteria presented below

	Typical	Maximum Steaming
Total Flow Rate (scfm)	300	500
Air Flow Rate (scfm)	150	50
Water Vapor Flow Rate (scfm)	150	450
Condensate generation (gpm)	0 8	2 5
Temperature (°F)	150	212
Pressure (inches Hg vacuum)	15	15
VOC Concentration (ppmv/v)	6,500	20,000
VOC removal rate (lbs/hr)	20-30	260
Total Water generated (gallons)	45,000	45,000
VOC Removal Efficiency	>95	>99

In addition, the offgas treatment alternatives need to be flexible, reliable, portable, and proven at the size and capacity being considered to meet the needs of the pilot tests and applicable for use with other waste streams at RFP Each of the alternatives needs to incorporate as much of the existing SVE equipment as possible into the overall treatment system The size of the system in the alternative must be capable of handling the maximum steaming conditions

6.2 DEVELOPMENT AND SCREENING OF ALTERNATIVES

Each of the retained technologies is developed into an offgas treatment alternative based on the above design criteria and described in the following sections. The alternative descriptions include process flow diagrams (PFDs), waste by-products generated, identification of new major equipment, modifications to the existing equipment, and utility requirements Cost estimates are prepared for each alternative Each of these alternatives is then evaluated with respect to effectiveness, implementability, and cost following the description of the alternative Table 6 2-1 summarizes key components of the effectiveness

and implementability of each alternative A summary of the overall evaluation is shown on Table 6 2-2

6.2.1 Existing GAC Alternative with Off-site Regeneration or Disposal

The existing SVE system with GAC offgas treatment is housed in a portable semi-truck trailer that can be moved to various sites to conduct pilot tests of the SVE technology The system is designed for an extraction capacity of 300-500 scfm at 10 inches of Hg vacuum. The system process flow is shown in Figure 6 2-1 The extraction system uses two blowers in series to provide vacuum. Two blowers were used for this application to minimize the size of the vacuum system to fit inside the trailer The existing offgas treatment system includes a knockout drum with a demister pad to remove entrained liquids from the extracted soil gas. During the SPSH pilot test, a condenser would be installed upstream of the knockout drum to remove water vapor or steam from the extracted soil gas stream The condensed water may require further treatment via air stripping prior to disposal. The exhaust gas from the air stripper would be routed back to the inlet of the existing knockout drum to remove any entrained liquid The condensate may require storage in additional storage tanks.

The extracted soil gas stream is routed through HEPA filters to remove particulates prior to treatment with GAC There is a potential that radioactive isotopes attached to particulates may be extracted with the soil gas If the GAC becomes contaminated with radioactive particles, it would become a mixed waste and limit the disposal or regeneration options

The two existing GAC units, 1,800 pounds each, are installed between the two extraction blowers The VOC concentrations in the gas stream after the second GAC unit are expected to be at or near non-detect levels. When organic breakthrough is observed between the two units, the lead unit will be taken off line The GAC media will be removed and replaced with new media, and the original lead unit put back on line as the second unit with the other GAC unit now as the lead unit

TABLE 6.2-2

ALTERNATIVE EVALUATION

Alternative	Effectiveness	Implementability	Cost
Existing GAC with Off-site Generation or Disposal	Effective in meeting cleanup goal Greater than 99 percent VOC removal	GAC is readily available Addition of a condenser would require minimal modification to the existing system Generates spent GAC that will require disposal or regeneration	Capital $187,000 to $427,000 O&M $552,000 to $569,000
Membrane Separation	Effective in meeting cleanup goal Greater than 99 percent VOC removal	Commercially available and compatible with existing equipment with major modifications Generates a concentrated organic liquid that will require further treatment/disposal	Capital $559,000 to $800,000 O&M $246,000 to $263,000
Ozone-UV-GAC	Effective in meeting cleanup goal GAC regenerated in situ 95-99 percent VOC removal by destruction	Commercially available and compatible with existing equipment with moderate modifications. Generates spent caustic that will require disposal	Capital $668,000 to $937,000 O&M $86,000 to $122,000
Adsorption/Condensation (Purus)	Effective in meeting cleanup goal 99 percent VOC removal	Commercially available and compatible with existing equipment with moderate modifications Generates a concentrated organic liquid that will require further treatment/disposal	Capital $731,000 to $971,000 O&M $214,000 to $231,000
Condensation/ Refrigeration	Effective in meeting cleanup goal Greater than 99 percent VOC removal	Commercially available and compatible with existing equipment with major modifications Generates a concentrated organic liquid that will require further treatment/disposal	Capital $445,000 to $687,000 O&M $215,000 to $232,000

TABLE 6.2-2
(Concluded)

Alternative	Effectiveness	Implementability	Cost	
Flameless Thermal Oxidation	Effective in meeting cleanup goal Greater than 99 percent VOC removal by destruction	Commercially available and compatible with existing equipment with moderate modifications Generates spent caustic that will require disposal	Capital O&M	$624,000 to $993,000 $103,000 to $167,000
Thermal Oxidation	Effective in meeting cleanup goal Greater than 99 percent VOC removal by destruction	Commercially available and compatible with existing equipment with moderate modifications Generates spent caustic that will require disposal	Capital O&M	$338,000 to $707,000 $107,000 to $170,000
Catalytic Oxidation	Effective in meeting cleanup goal 99 percent VOC removal by destruction	Commercially available and compatible with existing equipment with moderate modifications Generates spent caustic that will require disposal	Capital O&M	$923,000 to $1,480,000 $118,000 to $197,000

Effectiveness

This alternative would remove greater than 99 percent of the VOCs from the soil gas stream However, due to the high design concentrations of VOCs entering the GAC units, the GAC media will become saturated rapidly GAC replacement will be required approximately every 18 hours

Implementability

The majority of the equipment for this alternative is already at the site The alternative does require the addition of a condenser and potentially an air stripper and storage tanks to manage the water System operation requirements are limited to nominal electrical use and virgin or regenerated GAC By-products include HEPA filters, spent GAC media that may be disposed or regenerated off site, and condensate that may require treatment prior to discharge

The reliability of the GAC alternative for treating VOCs is high GAC has been used extensively to treat CCl_4 and other CHCs Inlet concentrations are limited to 10,000 ppmv/v to prevent a possible overheat situation Therefore, dilution air may be required The system is easily expanded to accommodate a higher VOC loading by installing more GAC columns, either in series or parallel Typical cost of an additional GAC vessel is $15,000 The GAC alternative is a fairly simple process with few major unit operations including condensation, GAC adsorption for VOC removal, and potentially air stripping

Cost

Capital and O&M cost estimates for the existing GAC alternative are shown in the Appendix on Tables A-1 and A-2 Capital costs range from approximately $187,000 to $427,000 O&M cost estimates for three months of operation range from approximately $552,000 to $569,000

6.2.2 Membrane Separation Alternative Using GAC Polishing

The membrane separation system would be a 600 scfm unit consisting of a compressor, refrigeration unit, and membrane module as shown in Figure 6 2-2. Upstream of the system, a condenser and knockout drum would remove the bulk of the moisture from the extracted gas stream The condensate generated may require treatment via an air stripper and storage The exhaust gas from the air stripper would be routed to the inlet of the knockout drum The membrane separation system first uses a compressor to increase the soil gas stream pressure to 150 psig and a refrigerant cooled heat exchanger to cool the soil gas stream to 35°F Condensate is removed and pumped to a storage tank. The soil gas stream then enters the membrane module, where it is separated into a VOC rich stream and a VOC depleted stream. The VOC rich stream is returned to the inlet of the compressor for reprocessing, and the VOC depleted stream is passed to the existing GAC units for polishing prior to discharge to the atmosphere

Modifications to the existing SVE unit include installation of a condenser upstream of the knockout drum, potential addition of an air stripper system to treat the condensate, and addition of the associated pumps and storage tanks The membrane separation unit would be a separate skid-mounted unit that would require piping modifications for installation upstream of the existing GAC units

Effectiveness

This alternative would remove greater than 99 percent of the chlorinated hydrocarbons The membrane separation process operated as described above requires GAC as a polishing step to remove CCl_4 This alternative with GAC polishing can meet the cleanup goal

Implementability

The equipment for this alternative is commercially available, and can be incorporated with the existing SVE equipment. This would require major modifications to the piping and existing system to install the membrane system between the knockout drum and GAC vessels. This alternative has no limit on the VOC inlet concentration or water content of the soil gas stream The power requirement for this alternative is approximately 167 kW for a 600 scfm unit By-products of this alternative would include the HEPA filters, potentially spent GAC, condensate which may require treatment prior to disposal, and a concentrated organic liquid that would require off site treatment and disposal

Cost

Capital and O&M cost estimates for the membrane separation alternative are shown in the Appendix on Tables A-3 and A-4. The cost of the membrane separation unit is approximately $200,000 Capital costs with supporting equipment required for this treatment alternative range from approximately $559,000 to $800,000 O&M cost estimates for three months of operation range from approximately $246,000 to $263,000

6.2.3 Ozone-UV-GAC Alternative

The ozone-UV-GAC system would be a 600 scfm unit consisting of three separate skid-mounted units that include a gas phase photolytic reaction chamber, a mist air dispersion reactor/scrubber unit and two new GAC units as shown in Figure 6 2-3. A heat exchanger (cooler) would reduce the temperature of the soil gas stream The extracted soil gas stream would enter the gas phase photolytic reactor chamber where the organics are oxidized by UV light in the presence of activated oxygen (ozone, etc) The soil gas stream is further oxidized and scrubbed in the mist air dispersion reactor and then transferred through to the GAC units The remaining VOCs and ozone in the soil gas stream are adsorbed onto the GAC An activated oxygen generation system is required to support oxidation and the GAC

regeneration step The remaining VOCs and ozone in the soil gas stream are adsorbed onto the GAC The GAC would be regenerated with activated oxygen on a daily basis Oxidation of chlorinated VOCs will generate HCl in the exhaust gas that requires scrubbing A caustic scrubbing system is included with the mist air dispersion reactor to provide offgas treatment for acid gas removal Chlorine would not normally be expected to reduce GAC adsorption capacity, although chlorine could ultimately reduce GAC capacity At the loading rates anticipated, the chlorine is not expected to degrade the GAC to a level that requires it to be replaced during the life of the pilot study

An additional blower, in conjunction with the existing blowers, will provide a minimal pressure drop across the ozone-UV-GAC unit The soil gas stream purged from the GAC vessels will be returned to the beginning of the treatment unit. The only additional waste product is the spent caustic scrubbing solution that may require treatment prior to disposal

Effectiveness

This alternative destroys greater than 95 percent of CCl_4, PCE, and TCE This alternative meets the requirements for the cleanup goal

Implementability

The equipment for this alternative is commercially available and can be incorporated into the existing SVE system with moderate modifications This system has no limitations on VOC inlet concentration This alternative requires an upstream heat exchanger (cooler), approximately 14 kW of electrical power, caustic, water and replacement ultraviolet lamps By-products that will be generated include spent caustic, UV lamps, HEPA filters, and eventually exhausted carbon.

This is a relatively new technology with a single vendor There are ten full scale systems currently operating at commercial manufacturing facilities which treat CHCs, but CCl_4 is not

the primary contaminant at these sites Therefore, the probability of reliable performance is estimated to be moderate. Expandability of the system is achievable by installing another activated oxygen generator This alternative employs numerous unit operations including the photolytic oxidation, scrubbing, activated oxygen generation, and adsorption

Cost

Capital and O&M cost estimates for the ozone-UV-GAC alternative are shown in the Appendix on Tables A-5 and A-6

The cost of the ozone-UV-GAC unit is approximately $285,000 With the supporting equipment required for this treatment alternative, the capital cost is approximately $668,000 to $937,000 O&M cost estimates for three months of operation range from approximately $86,000 to $122,000

6.2.4 Adsorption/Condensation Alternative Using Purus Technology

This alternative includes a 500 scfm adsorption/condensation unit The extracted soil gas stream will first pass through a condenser and the existing knockout drum to remove significant quantities of water from the gas stream. The condensate may require treatment via an air stripper to remove entrained VOCs before storage or disposal The soil gas stream from the condenser will pass through HEPA filters to remove particulates. The condenser will cool the gas stream to approximately 40°F The maximum inlet temperature for the Purus module is 120°F The Purus system would be installed after the lead blower as shown in Figure 6 2-4 A series of adsorption beds would remove the VOCs from the extracted soil gas As one set of beds is treating the soil gas stream, the other set is being regenerated The regeneration process uses internal heating coils in the adsorption beds to monitor the temperature of the adsorbent A vacuum pump also lowers the operation pressure to help volatize the VOCs The VOCs from the regeneration cycle are condensed in a two-stage condenser system operation A mechanical refrigeration system provides

coolant for the condensing step Nitrogen gas is also used to purge the adsorption bed of VOCs prior to further on-line use The concentrated organic liquid is transferred to an on-site storage tank for eventual disposal The pressure drop across the Purus module is 16 to 20 inches of water column

Modifications to the existing SVE unit include installation of a new condenser before the existing knockout drum, potential addition of an air stripper system to treat the condensate, and addition of the skid-mounted Purus module The concentrated organic liquid would require offsite treatment and disposal

Effectiveness

This alternative would remove 95 to 99 percent of the CCl_4 and 99 percent of the PCE and TCE, the major contaminants in the gas stream It removes both chlorinated and nonchlorinated compounds, and thus can meet the cleanup goal

Implementability

The Purus technology in this alternative is technologically mature and commercially available This alternative can be merged with the existing equipment with moderate modifications. High VOC inlet concentrations can be accepted but the loading on the resins and desorption rate would be affected A soil gas stream with 100 percent relative humidity can be accepted by this alternative This alternative requires approximately 20 to 30 kW of electrical power and compressed nitrogen gas By-products include HEPA filters, the condensate, and the concentrated organic liquid that would require off-site treatment and disposal

While this is a relatively new technology with a single vendor, there are about ten full-scale units treating CHCs Therefore, the probability of reliable performance is estimated to be moderate The adsorbent beds are modular units, allowing easy additions to increase the

removal capacity This alternative involves numerous unit operations including condensation, air stripping, adsorption, and refrigeration.

Cost

Capital and O&M cost estimates for the adsorption/condensation alternative are shown in the Appendix on Tables A-7 and A-8

The cost of the Purus module is $300,000 With the supporting equipment required for this treatment alternative, the capital cost is approximately $731,000 to $971,000 O&M cost estimates for three months of operation range from approximately $214,000 to $231,000

6.2.5 Condensation/Refrigeration Alternative Using GAC Polishing

The condensation/refrigeration system would be a 500 scfm unit as shown in Figure 6 2-5 The extracted soil gas stream will pass through a condenser to remove significant quantities of water from the gas stream. The condensate will be collected and may require treatment via air stripping to remove VOCs before storage or disposal The soil gas stream exiting the condenser at 40°F will pass through HEPA filters to remove particulates. The condensing system will be installed after the lead blower, and the existing GAC units and blowers could be used in their existing configurations The condensers would be skid mounted and installed adjacent to the trailer. A mechanical refrigeration system would provide cooling media to lower the soil gas stream temperature and promote further condensing of VOCs Because the operating temperature of -30°F is well below the freezing point of water, dual heat exchanger units would be installed in parallel The system will be automatically switched over to the second heat exchanger while the original system thaws The concentrated organic liquid would require offsite treatment and disposal. The condensing system with the existing GAC units will provide a VOC removal efficiency of greater than 99 percent

Modifications to the existing SVE unit would include installation of a condenser upstream of the knockout drum, potential addition of an air stripper system to treat the condensate, and addition of a skid-mounted refrigeration system with a recovery tank upstream of the existing GAC units

Effectiveness

This alternative would remove greater 99 percent of CCl_4, PCE, and TCE, in addition to nonchlorinated and other chlorinated compounds in the soil gas stream The GAC is required for polishing to adsorb primarily CCl_4, which is difficult to condense. This alternative can meet the cleanup goal

Implementability

The equipment for this alternative is commercially available and is typical of the processes used in the chemical manufacturing industry Therefore, this type of process would be moderate in reliability. This alternative would require major modifications to incorporate the existing equipment. This alternative has no restrictions on the VOC inlet concentration or water content of the soil gas stream The power requirements are approximately 44 kW This process involves numerous unit operations including condensation, refrigeration, air stripping, and adsorption. Multiple units could be added to expand the capability of this system By-products include HEPA filters, the condensate, potentially spent carbon, and the concentrated organic liquid that requires off-site treatment and disposal

Cost

Capital and O&M cost estimates for the condensation/refrigeration alternative are shown in the Appendix on Tables A-9 and A-10

The cost of the condensation/refrigeration equipment is approximately $150,000 With the supporting equipment required for this treatment alternative, the capital cost is approximately $445,000 to $687,000 O&M cost estimates for three months of operation range from approximately $215,000 to $232,000

6.2.6 Flameless Thermal Oxidation Alternative

The flameless thermal oxidizer would be a 1,000 scfm unit as shown in Figure 6 2-6 The soil gas stream would pass through a condenser to remove most of the water The condensate may require treatment by an air stripping system prior to storage and disposal. The soil gas stream would pass through HEPA filters to the flameless thermal oxidizer system The oxidizer is a carbon steel shell with refractory lining and contains a packed bed matrix that supports the oxidation process The oxidizer operates at approximately 1800°F The preheater is used to heat the oxidizers' ceramic bed on system startup and provide supplemental fuel as needed to maintain the matrix at the operating temperature. The VOCs are oxidized to CO_2, H_2O, and HCl The exhaust gas from the oxidizer passes through a quench unit for cooling The exhaust gas is routed to a scrubber where the HCl would be neutralized by scrubbing with caustic The scrubber system would include a caustic supply tank, fresh water supply tank, scrubber with recirculation pump, and a spent caustic solution storage tank No treatment of the spent scrubber solution is assumed at the pilot test site The scrubber system could be installed on the oxidizer skid or on a separate skid The scrubber system, caustic storage, and mixing systems are assumed to be inside a secondary containment area or designed with double walled system and leak detection

The existing lead blower in the SVE pilot unit should generate enough pressure without limiting the vacuum generation capability The existing configuration of the two blowers operating in series will have to be modified as the thermal oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate. There is also the potential that the existing blower may also need to be replaced with one blower The flameless thermal oxidizer would be an external skid mounted unit The organic treatment

will be operated above atmospheric pressure This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation A propane storage tank would be used to provide fuel for startup and supplemental fuel for operation

Modifications to the existing SVE unit would include installation of a condenser upstream of the existing knockout drum, potential addition of an air stripper system, and the installation of the skid-mounted flameless thermal oxidizer system with potentially a caustic scrubber unit

Effectiveness

This alternative would remove greater than 99 percent of the CCl_4, PCE and TCE in addition to nonchlorinated and other chlorinated compounds in the gas stream, and would meet the cleanup goal

Implementability

The flameless thermal oxidation system is commercially available and has been used at five sites for treatment of nonchlorinated and chlorinated compounds of which two sites are treating CCl_4 This oxidation system can be incorporated into the existing equipment with moderate modifications. The oxidizer system requires approximately 45 to 52 kW of power This alternative has no limitations on inlet VOC concentrations and would be fairly insensitive to changes in concentration

The capacity or size of the flameless thermal oxidizer system could be expanded in the design phase by including a larger blower, larger burner, and additional valving which may add some to the capital costs. This alternative includes several unit operations including condensation, air stripping, flameless thermal oxidization, and acid gas scrubbing The by-

products from this alternative, HEPA filters, condensate, and spent caustic, may require treatment prior to disposal.

Cost

Capital and O&M cost estimates for the Flameless Thermal Oxidation Alternative are shown in the Appendix on Tables A-11 and A-12 The cost of the flameless thermal oxidizer equipment is approximately $270,000 Total capital costs with the supporting equipment required for this treatment alternative are approximately $624,000 to $993,000 O&M cost estimates for three months of operation range from approximately $103,000 to $167,000

6.2.7 Thermal Oxidation Alternative

The thermal oxidation unit would be a 2,500 scfm unit that would be skid mounted, nominally 6 feet wide by 12 feet long, replacing the existing GAC units as shown in Figure 6 2-7 The extracted soil gas stream would pass through a condenser operating at 40°F to remove the majority of the water The condensate would be removed and may require treatment via an air stripper prior to storage and disposal. The soil gas stream would pass through HEPA filters for particulate removal After exiting the filters, the soil gas stream would enter the thermal oxidizer. A porous ceramic burner mixes the soil gas, combustion air, and fuel before combustion in the thermal oxidizer The oxidizer operating temperature ranges from 1400°F to 1800°F The exhaust gas from the oxidizer contains HCl and may require further treatment before discharge to the atmosphere The exhaust gas would undergo scrubbing with a caustic solution in the acid gas scrubber, removing greater than 99 percent of the HCl The scrubber system would include a caustic supply tank, fresh water supply tank, scrubber with recirculation pump, and a spent caustic solution storage tank No treatment of the spent caustic solution is assumed at the pilot test site The scrubber system, caustic storage, and mixing systems are assumed to be designed with double walls and leak detection

The existing lead blower in the SVE pilot unit should generate enough pressure generation capacity without limiting the vacuum generation capability The existing configuration of the two blowers operating in series will have to be modified as the oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate The thermal oxidizer typically operates above atmospheric pressure This system can be designed, installed, and operated to provide the necessary treatment without having the treatment system designed for vacuum operation A propane storage tank would be used to provide fuel for startup and supplemental fuel for operation The exhaust gas from this alternative contains less than 5 ppmv/v NO_x

Modifications to the existing SVE unit include installation of a condenser upstream of the existing knockout drum, potential addition of an air stripper system, and installation of the skid-mounted thermal oxidizer system with potentially a caustic scrubber unit

Effectiveness

This alternative would remove greater than 99 percent of the CCl_4, PCE, and TCE in addition to nonchlorinated and other chlorinated compounds in the gas stream and would meet the cleanup goal

Implementability

The thermal oxidation system is commercially available and has been proven to be effective at removing CCl_4 The existing equipment can be incorporated into this alternative with moderate modifications This oxidizer system requires approximately 7 to 14 kW of electric power and propane as the fuel source This alternative has a 5,000 to 6,000 ppmv/v maximum VOC concentration limit on the inlet to the oxidizer The pressure drop across the thermal oxidizer is 5 inches of water column The oxidizer system operates more effectively with air streams at less than 80 percent relative humidity More water vapor content increases the fuel consumption and dilution air requirements

The thermal oxidation technology is commercially available. The capacity or size of the thermal system could be expanded in the design phase by including a larger blower, larger burner, and increased valving which may add some to the capital costs This alternative includes several unit operations including condensing, air stripping, thermal oxidization, and acid gas scrubbing

By-products from this alternative would be HEPA filters and potentially a spent caustic solution that may require further treatment prior to disposal

Cost

Capital and O&M cost estimates for the thermal oxidation alternative are shown in the Appendix on Tables A-13 and A-14 The cost of the thermal oxidizer equipment is approximately $73,000 Total capital costs with the supporting equipment required for this treatment alternative are approximately $338,000 to $707,000 O&M cost estimates for three months of operation range from approximately $107,000 to $170,000

6.2.8 Catalytic Oxidation Alternative

The catalytic oxidation system would be a 4,400 scfm unit similar in process flow to the thermal oxidation shown in Figure 6 2-7 The size of the catalytic oxidation unit is increased over the size of the other thermal units to add additional dilution air to maintain a 5,000 ppmv/v inlet concentration The extracted soil gas stream would pass through a condenser to remove the majority of the water vapor The condensate may require treatment via air stripping prior to storage and disposal The soil gas stream then passes through the HEPA filters and to the catalytic oxidizer The catalytic oxidizer operates at an inlet temperature of 650°F and an exhaust temperature of 850°F The soil gas stream passes through the catalyst where an exothermic reaction converts the VOCs to CO_2, water, and HCl

The exhaust gas from the oxidizer may require further treatment to neutralize HCl The scrubber system would include a caustic supply tank, fresh water supply tank, scrubber with recirculation pump, and a spent caustic solution storage tank No treatment of the spent caustic solution is assumed at the pilot test site. The scrubber system and caustic storage tanks are assumed to be inside a secondary containment area or designed with double walls and leak detection

The existing lead blower in the SVE pilot unit should generate enough pressure capacity without limiting the vacuum generation capability. The existing configuration of the two blowers operating in series will have to be modified as the oxidizer and scrubber system are typically not designed for the vacuum pressures the SVE system can generate The catalytic oxidizer typically operates above atmospheric pressure This system can be designed, installed, and operated to provide the necessary treatment without having all the treatment system designed for vacuum operation A propane storage tank would be used to provide fuel for startup and supplemental fuel for operation The exhaust gas would contain approximately 40 ppmv/v of NO_x at 3 percent oxygen

Modifications to the existing SVE unit include installation of a condenser upstream of the existing knockout drum, potential addition of an air stripper system, and installation of the skid-mounted catalytic oxidizer system with the caustic scrubber unit

Effectiveness

This alternative would remove greater than 99 percent of the CCl_4, PCE, and TCE in addition to nonchlorinated and other chlorinated compounds in the air stream and would meet the cleanup goals

Implementability

The catalytic oxidation system is commercially available and has been proven on a full scale operation to be effective at removing CCl_4, PCE, and TCE The existing equipment could be modified and incorporated into the overall treatment system with moderate modifications. The oxidizer system requires only 8 to 15 kW of electrical power, but would require supplemental fuel for maintaining the oxidizer temperature. The pressure drop across the catalytic oxidizer system is 8 inches of water column. The inlet concentration to the oxidizer has a limit of 5,000 ppmv/v VOC and can operate at 100 percent relative humidity in the gas stream For higher inlet concentrations, dilution air is required to reduce the concentrations At high relative humidities, additional fuel is required

The technology has been used at more than a dozen sites at full scale operation to treat CHCs Therefore, its reliability would be moderate to high Enlargement of the system in the design phase is preferable to modifying an existing system This advance design will allow for partitioning of the catalyst site, for later scaling up if necessary This alternative includes several unit operations including condensation, air stripping, catalytic oxidization, and acid gas scrubbing

This alternative would generate spent HEPA filters and a spent caustic solution which may require further treatment prior to disposal

Cost

Capital and O&M cost estimates for the catalytic oxidation alternative are shown in the Appendix on Tables A-15 and A-16 The cost of the catalytic unit is approximately $415,000 Total capital costs with the supporting equipment required for this treatment alternative are approximately $923,000 to $1,480,000 O&M cost estimates for three months of operation range from approximately $118,000 to $197,000

6.3 COMPARISON OF ALTERNATIVES

The alternatives described and evaluated in Section 6 2 are further evaluated by comparison to each other. Tables 6 2-1 and 6 2-2 present how each alternative meets key requirements such as implementability, reliability, commercial availability, and expandability and summarizes the effectiveness, implementability, and cost of each alternative

All of the alternatives are capable of achieving a minimum removal efficiency of 95 percent or greater for VOCs Ozone-UV-GAC has achieved greater than 95 percent removal efficiencies for VOCs for units currently in operation at commercial and industrial facilities These units have successfully maintained emissions compliance with the California South Coast Air Quality Management District requirements The adsorption/condensation and catalytic oxidation alternatives each have been reported to achieve 99 percent removal of VOCs Condensation/refrigeration, flameless thermal, and thermal oxidation alternatives have been reported to achieve greater than 99 percent removal of VOCs The flameless thermal oxidation units have successfully maintained emissions compliance with the Bay Area Air Quality Management requirements

All of the alternatives except ozone-UV-GAC will require a condensing step prior to treatment to remove the water from the soil gas stream Ozone-UV-GAC system uses the aqua reactor/scrubber for condensing water vapor from the gas stream Most of the alternatives can operate at 100 percent RH inlet conditions but would operate more effectively at less than 100 percent RH

Only the oxidation alternatives (thermal, catalytic, and flameless thermal) will generate products of combustion ($C0_2$ and H_2O), including HCl and NO_x NO_x is regulated for this site NO_x generated by the alternatives will be small quantities that are within the regulatory limits Ozone-UV-GAC will not generate NO_x since it operates at ambient temperatures but will generate HCl HCl is a hazardous air pollutant but is not regulated at this time For this evaluation, a caustic scrubbing system capable of approximately

99 percent removal has been included as a reasonable control alternative for each of these alternatives The scrubbing process will generate a spent caustic waste from the removal of HCl and carbon dioxide that may require treatment before disposal Treatment of the spent caustic at the RFP 374 Evaporator facility may be an option

While all of the alternatives are commercially available, two of the technologies (adsorption/ condensation and ozone-UV-GAC) are considered proprietary and available from one source

All of the alternatives have been used on chlorinated organic streams containing CCl_4 The adsorption/condensation (Purus) alternative has been demonstrated at more than ten sites Most of the other alternatives have been demonstrated at fewer than ten sites Some of the alternatives use conventional processes such as condensation, refrigeration, and adsorption that have been used in the chemical industry for years The oxidation alternatives, particularly thermal, use a process that has been used in the chemical and refining industries for years The alternatives that use conventional processes will tend to be more reliable than other processes

The simplest alternative with the least number of unit operations is the GAC alternative Although GAC appears to be the simplest, it would also be operation intensive due to frequent carbon change outs at the higher inlet VOC concentrations The oxidation alternatives would be relatively simple if treatment of the condensate and scrubbing of the exhaust gas to neutralize acids were not required The oxidation unit would be the only major process equipment. There would be three major process units in the ozone-UV-GAC system in addition to the activated oxygen generators The VOC recovery type alternatives (adsorption/condensation, condensation/refrigeration, membrane separation) involve more process operations but the processes are conventional. The condensation/refrigeration and membrane separation alternatives could encounter operating problems with icing and thermal cycling With a more complex system, more complex operation will result from the multiple unit operations

Several of the alternatives are more flexible and can be expanded more easily after the system has been built The capacity or size of the thermal, catalytic, and flameless thermal oxidation alternatives would be more easily and cost effectively expanded in the detailed design phase

The GAC alternative would produce the largest quantity of by-product (spent GAC) that would require off-site treatment and disposal The VOC recovery type alternatives (adsorption/condensation, condensation/refrigeration, membrane separation) would also generate a significant quantity of concentrated organics that would require treatment and disposal, probably incineration Final disposition of the spent carbon or organic liquid would depend on their chemical profiles For this evaluation, costs were obtained from potential off-site treatment/disposal facilities but acceptance of these wastes was not confirmed

Although GAC and the VOC recovery type alternatives are capable of meeting the removal efficiency, the implementability of these alternatives would be more complex due to frequent carbon change out with GAC, multiple process units requiring greater and more frequent maintenance, and the generation of wastes requiring acceptance at an off-site treatment/disposal facility Therefore the GAC, adsorption/condensation, condensation/refrigeration, and membrane separation alternatives will not be retained for further consideration as the off gas treatment alternative

The ozone-UV-GAC, thermal, catalytic, and flameless thermal are all destruction alternatives These alternatives involve fewer unit operations and would generate a potentially nonhazardous spent caustic solution that could be treated and disposed on-site Depending on VOC destruction requirements, quantities of caustic for disposal may be significant Therefore, the destruction alternatives appear to be more compatible, reliable, and effective at removing the VOCs

Of the oxidation alternatives, the catalytic oxidation alternative would require a much larger system (4,400 scfm) capable of handling the maximum steaming conditions, because a large

volume of dilution air is required to maintain its effective operating temperature and to protect the catalyst at high inlet VOC conditions Its size makes it more costly to achieve the same removal efficiency. This alternative will not be retained for further consideration

The ozone-UV-GAC alternative has been used on a much larger scale treating 300,000 to 500,000 scfm of VOC laden exhaust air from commercial manufacturing sites and has successfully demonstrated compliance with discharge standards for chlorinated VOCs This alternative is expected to achieve the same removal efficiency in a smaller scale unit Implementability of this alternative will be more complex than a thermal oxidation unit due to the multiple unit operations Therefore, this alternative may be considered a potential alternative should the simpler oxidation systems be imposed with more stringent offgas removal requirements

The thermal and flameless thermal oxidation alternatives are similar in cost and can achieve the desired removal efficiencies These types of units are currently being used at chemical, automotive, and military facilities and at refineries for treating chlorinated compounds Thermal oxidation, which is similar to flaring performed at chemical plants and refineries, would be a very simple cost effective and reliable method of offgas treatment for this type of unit

6.4 SUMMARY AND RECOMMENDATIONS

As a result of the alternative screening and evaluation process, the thermal oxidation alternative is recommended as the offgas treatment alternative

The thermal oxidation employs a simple, proven process widely used in the chemical and refinery industries Advantages of the thermal oxidation alternative include greater than 99 9 percent destruction of VOCs compared to 95% removal or destruction by other alternatives, generation of few non-hazardous by-products, simple process operation therefore

greater reliability in operation, and is a cost effective technology that can be used for a wide range of concentrations as anticipated with SPSH

This technology has been used and proven at numerous sites for destruction of chlorinated organics and would work well with the innovative technology being tested (SPSH) to more quickly remediate the soil at Trench T-3

The system is fairly insensitive to changes in concentrations and will be able to handle the wide range anticipated with the SPSH and can operate at concentrations outside the anticipated range The system can also operate at lower flow rates should site conditions prevent attainment of typical or maximum steaming design conditions

The design of a thermal oxidation system can be implemented in a timely manner During this design, the treatment/disposal of the spent caustic at the RFP 374 Evaporator Facility will be evaluated In addition, options for treatment and disposal of the condensate will be further evaluated Contingencies such as using the existing GAC and reducing vacuum and temperature during SPSH will also be considered in the detailed design phase

7.0 REFERENCES

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APPENDIX
COST ESTIMATES FOR OFFGAS TREATMENT ALTERNATIVES

COST ASSUMPTIONS

The cost tables developed for each of the offgas treatment alternatives in this Appendix are order of magnitude estimates The range of accuracy for these estimates is typically assumed to be +50 percent/-30 percent The following summarizes the assumptions that were required in order to develop the cost tables for each of the offgas treatment alternatives

Capital Cost Assumptions·

- The existing GAC alternative capital cost estimate incorporates the cost for replacement carbon. The frequency of GAC replacement is assumed to be every 18 hours based on 15 percent loading and inlet VOC concentration of approximately 6500 ppmv/v The cost for GAC replacement includes delivery of virgin carbon (about $1 28 per pound) and regeneration of the spent carbon (about $1 07 per pound) For alternatives using GAC as a polishing step, it is assumed that GAC loading rates are 25 times lower, which would require only 8,640 lbs of GAC for the duration of the pilot test

- A condenser is required to remove water vapor from the SVE gas stream in order to maintain the efficiency of the HEPA filters and to meet requirements of the offgas treatment technologies

- The condensate stream with entrained VOCs may need to be treated Two capital and O&M cost tables were developed for each alternative one with and one without water treatment For these estimates, the water treatment system is included to remove VOCs from the condensate stream and is assumed to be an air stripper system that includes an air stripping tower with packing and a sump, a blower, pumps, and instrumentation and controls Treated water will be stored in five 10,000 gallon, double walled tanks Two 10,000 gallon, double walled tanks from the existing SVE treatment system will be used to temporarily hold the condensate prior to treatment

- An acid gas scrubber is incorporated as part of the offgas treatment system to remove HCl from the gas stream for those alternatives using oxidation/destruction technologies The scrubber system would include double walled tanks for the caustic and the spent caustic and a single walled tank for water storage The size of the acid scrubber varies with the size of oxidation/destruction system Costs for the acid scrubber were included with the quote from the oxidation/destruction system suppliers.

- Propane is assumed to be the fuel supplement for the thermal and catalytic oxidation alternatives

- A 10,000 gallon, double walled tank is also required for condensed organic liquid storage for the adsorption/condensation and condensation/refrigeration alternatives that recover VOCs in liquid form

- For this cost estimate, it is assumed that each system will be a self-contained skid or trailer mounted unit that will require utility, piping, electrical and instrumentation hookups Some site preparation and additional trailer space is also assumed to be required Therefore, a lump sum estimate has been used for other direct costs

Operations and Maintenance Cost Assumptions.

- The system will be operated 7 days per week, 24 hours per day for 90 days for Pilot Test Site No 2

- It is assumed that two operators are required on site during the entire test period They will each devote four hours per day to the offgas treatment alternative A supervisor and a site safety officer will each devote four hours per week to the offgas treatment alternative Other health and safety costs are due to miscellaneous personal protection equipment (PPE)

- Electric utility costs are $0 08/kWh

- Raw materials include GAC, propane, and caustic. The thermal oxidation alternative is assumed to require twice as much propane as the catalytic oxidizer

- Hazardous waste disposal costs will include costs for concentrated VOC liquid disposal and spent GAC regeneration Disposal costs per drum have been assumed to be $275 (per telephone discussions with offsite treatement disposal facilities)

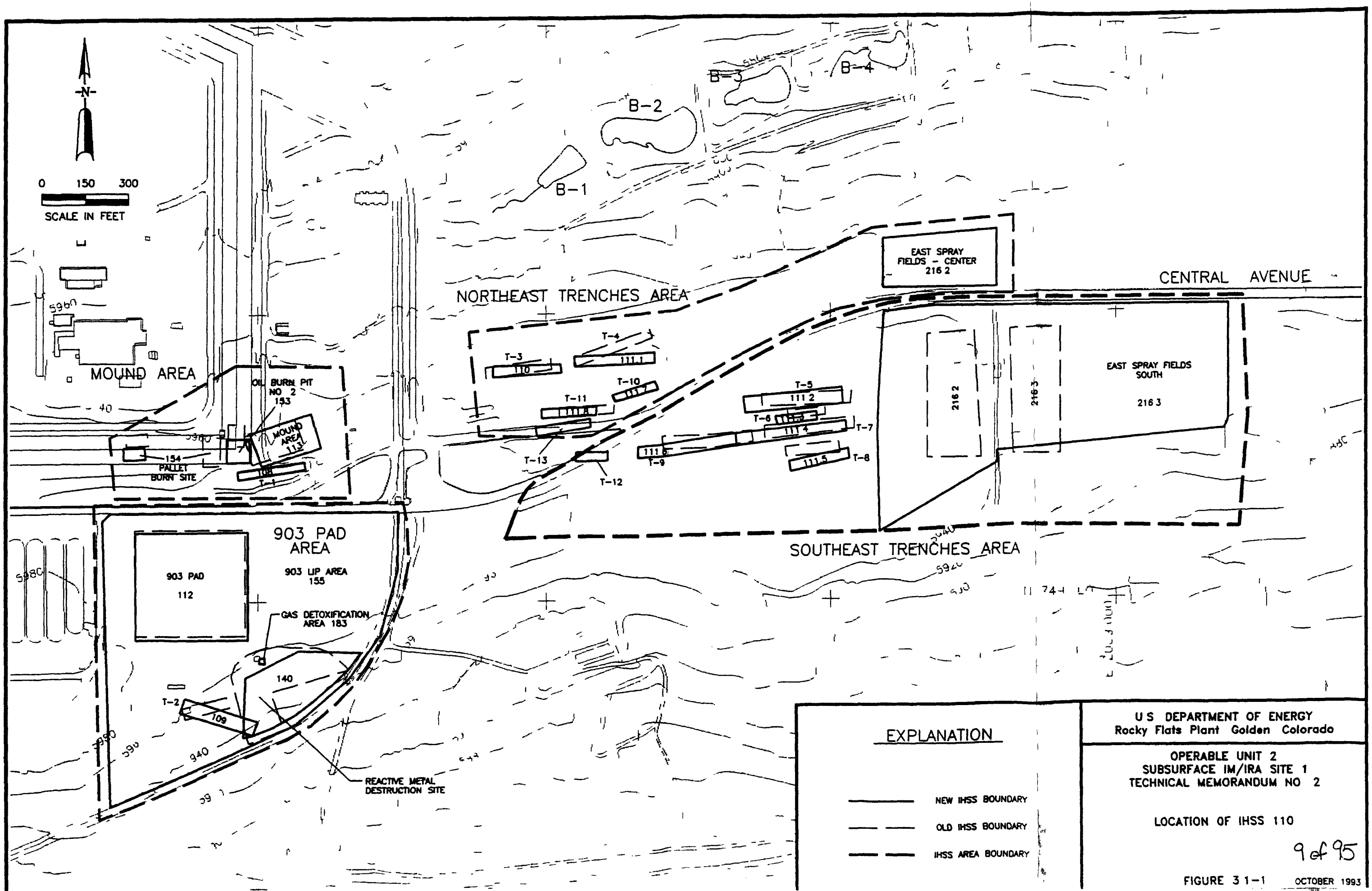
  Regeneration costs for spent GAC are based on $1 07 per pound for treatment It is assumed that HEPA filters will be disposed of on site The first of the two cost tables for each alternative assumes that the condensate will remain on site and be treated at either the 881 Hillside water treatment unit, or the OU-2 Field Treatment Unit The second cost table includes capital costs for a new air stripping system to treat the condensate.

  Spent caustic treatment and disposal costs are not included It is assumed that this waste stream will remain on site and be treated at the RFP 374 Evaporator Facility

Other Assumptions

- Permanent (hard line) electrical power is assumed to be available Therefore, no costs for operations and maintenance of portable diesel generators are included

- Process water is available



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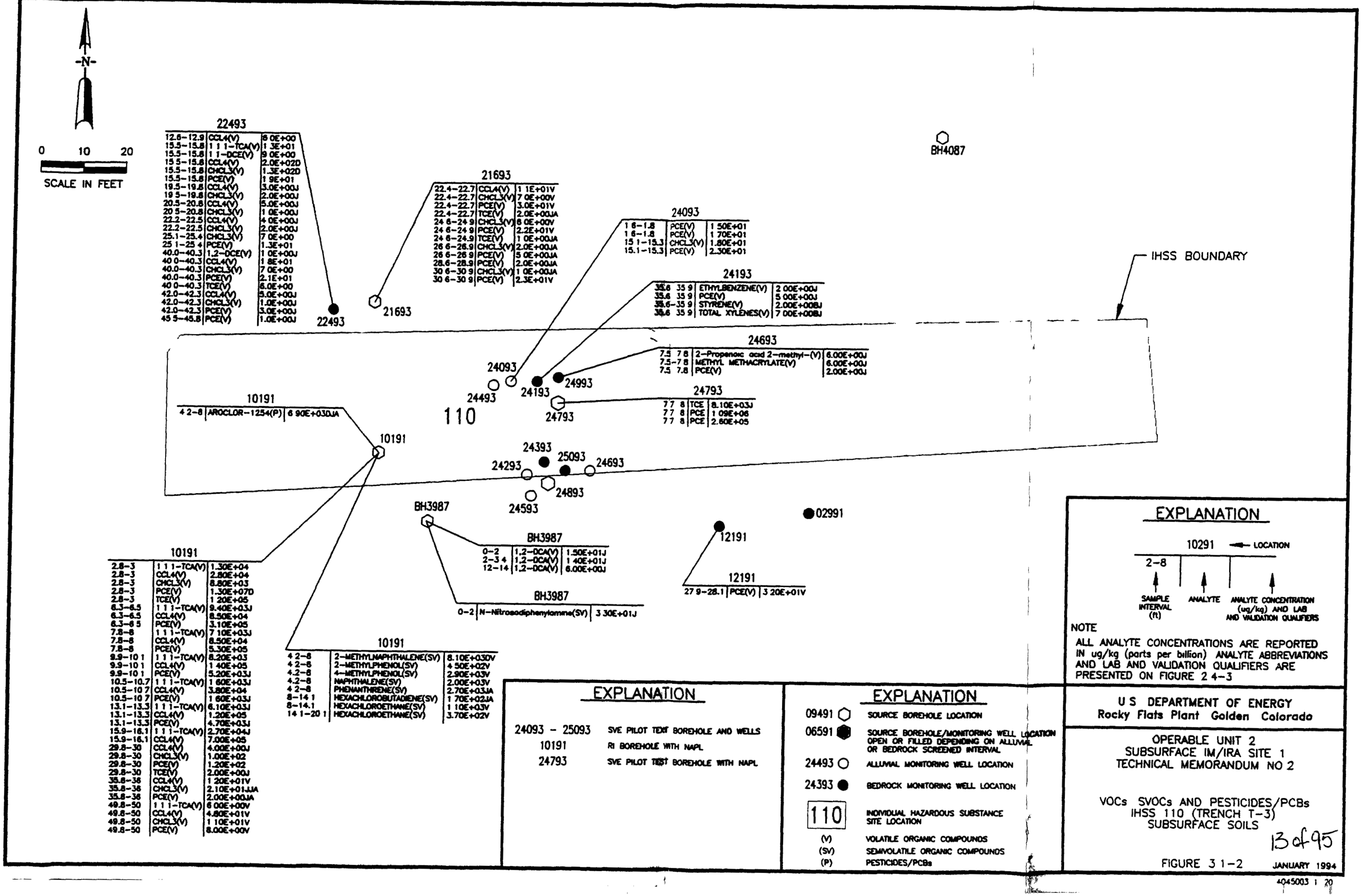
OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

LOCATION OF IHSS 110

FIGURE 3 1-1 OCTOBER 1993



EXPLANATION

24093 – 25093	SVE PILOT TEST BOREHOLE AND WELLS
10191	RI BOREHOLE WITH NAPL
24793	SVE PILOT TEST BOREHOLE WITH NAPL

EXPLANATION

09491 ⬡	SOURCE BOREHOLE LOCATION
06591 ⬢	SOURCE BOREHOLE/MONITORING WELL LOCATION OPEN OR FILLED DEPENDING ON ALLUVIAL OR BEDROCK SCREENED INTERVAL
24493 ○	ALLUVIAL MONITORING WELL LOCATION
24393 ●	BEDROCK MONITORING WELL LOCATION
110	INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION
(V)	VOLATILE ORGANIC COMPOUNDS
(SV)	SEMIVOLATILE ORGANIC COMPOUNDS
(P)	PESTICIDES/PCBs

EXPLANATION

NOTE

ALL ANALYTE CONCENTRATIONS ARE REPORTED IN ug/kg (parts per billion) ANALYTE ABBREVIATIONS AND LAB AND VALIDATION QUALIFIERS ARE PRESENTED ON FIGURE 2 4–3

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OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

VOCs SVOCs AND PESTICIDES/PCBs
IHSS 110 (TRENCH T–3)
SUBSURFACE SOILS

13 of 95

FIGURE 3 1–2 JANUARY 1994

4045003 1 20

WEST

EAST

IHSS 110

20

10191

BH3987

CCl4 CHCl3 PCE TCE 1,2-DCA 1 1 1 TCA (µg/kg)

GROUND SURFACE

Qrf

Ka

Ka(No 1)

T/BR

NOT DETECTED

ELEVATION (ft)

5970
5960
5950
5940
5930
5920
5910
5900

VERTICAL 0 — 10 SCALE IN FEET

NOTE HORIZONTAL DISTANCE NOT TO SCALE

N CROSS-SECTION LOCATION MAP

MOUND AREA

EAST TRENCHES AREA

903 PAD AREA

EXPLANATION

T/BR = TOP OF BEDROCK

= LOCATION SYMBOL

3486 = LOCATION NAME

5812.00 = GROUND SURFACE ELEVATION (ft)

EACH CHEMICAL IS PLOTTED ON A LOGARITHMIC SCALE (INCREASING TO RIGHT) FROM 1 TO 1 000 000 (µg/kg) DATA POINT REPRESENTS TOP OF SAMPLING INTERVAL.

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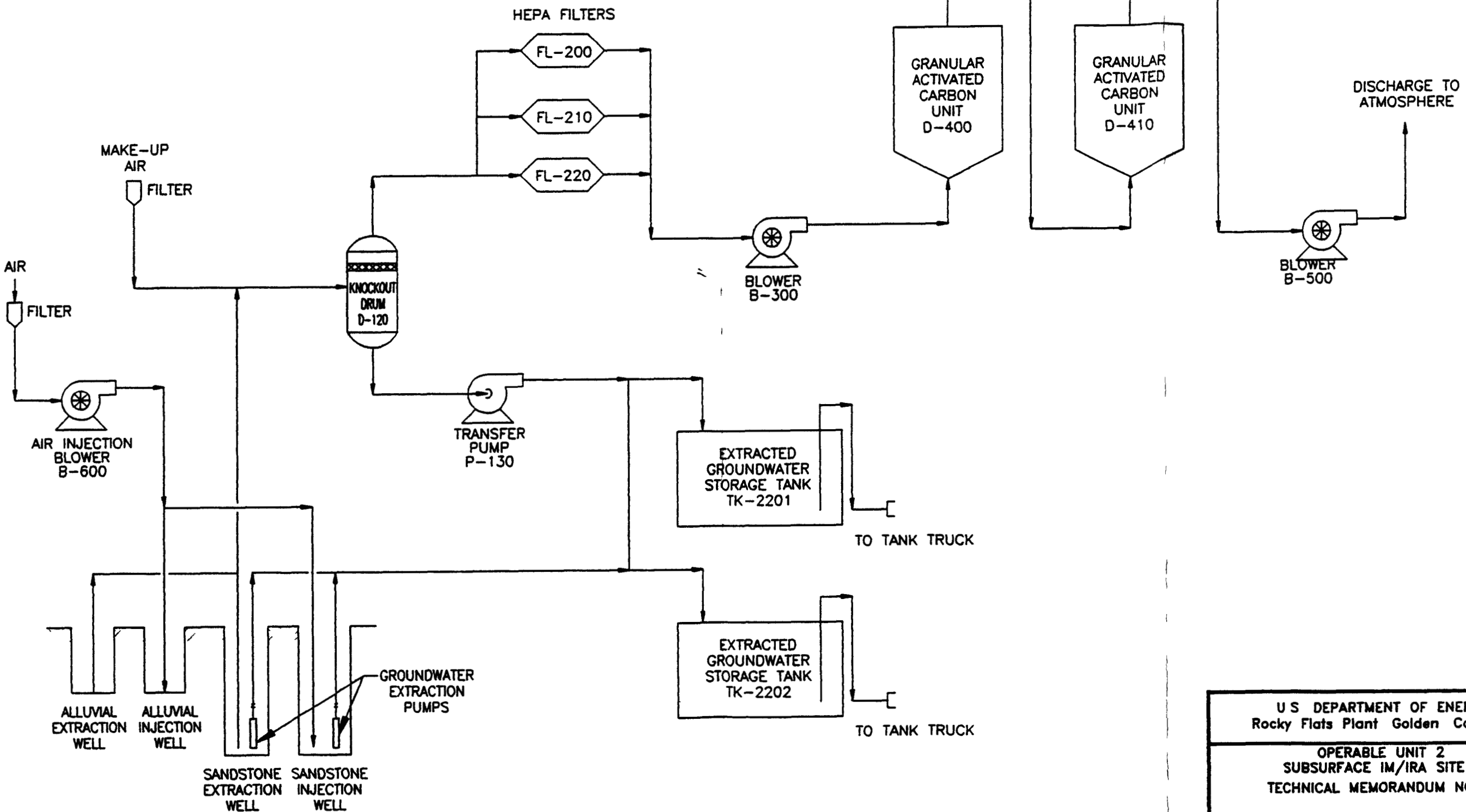
OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

SOURCE BOREHOLE CROSS-SECTION IHSS 110 (TRENCH T-3)

14 of 95

FIGURE 3 1-3 JANUARY 1994



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OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

SOIL VAPOR EXTRACTION
PROCESS FLOW DIAGRAM

FIGURE 4 1-1 JANUARY 1994

4045006 1=1

TABLE 6 2-1
ALTERNATIVE COMPARISON

	Carbon Tetrachloride removal efficiency	PCE Removal Efficiency	TCE Removal Efficiency	Maximum VOC limit	Maximum single contaminant conc	Maximum water vapor	Maximum inlet temperature	NO production rate	HCl production rate	Power requirements	Delivery time
Existing GAC with Offsite Regeneration	Greater than 99%	Greater than 99%	Greater than 99%	10 000 ppm	10 000 ppm			none	none	14 21 kW	4-6 weeks
Membrane Separation	95%	95%	95%	No limit	No limit	No limit (water goes through membrane)	NA	none	none	167 174 kW	14 weeks
Ozone UV-GAC	95 98%	95 98%	95 98%	No limit	No limit	100% Relative Humidity (RH) and droplets are not are concern	160 F	none	37.3 lb/hr	14 21 kW	8 weeks
Adsorption/ Condensation	95 99%	99%	99%	5,300 ppm	5,300 ppm	100% RH	120 F	none	0	21 27 kW	8 weeks
Condensation/ Refrigeration	Greater than 99 9%	99%	99%	900 000 ppmv/v	900 000 ppmv/v	100% of flow	NA	none	0	44 51 kW	16 weeks
Flameless Thermal Oxidizer	Greater than 99%	Greater than 99%	Greater than 99%	Thermal limit is 2 MMBTU/hr (Max. steaming conditions provide 403 000 BTU/hr)	Thermal limit is 2 MMBTU/hr	80% RH although a knockout drum for condensate will allow 100% RH.	none	<2 ppm	37.3 lb/hr	45 52 kW	14-20 weeks
Thermal Oxidizer	Greater than 99%	Greater than 99%	Greater than 99%	5 000-6 000 ppm		80% RH Reheat before going to thermal unit. A larger water loading would require greater fuel and air consumption.	none	<5 ppm	37.3 lb/hr	7 14 kW	16 weeks
Catalytic Oxidizer	Greater than 99%	Greater than 99%	Greater than 99%	10 000 ppm v with no dilution (no limit otherwise)	10 000 ppm v with no dilution (no limit otherwise)	100% RH, which would require supplemental fuel	none	40 ppm @ 3%	37.3 lb/hr	8 15 kW	10 weeks

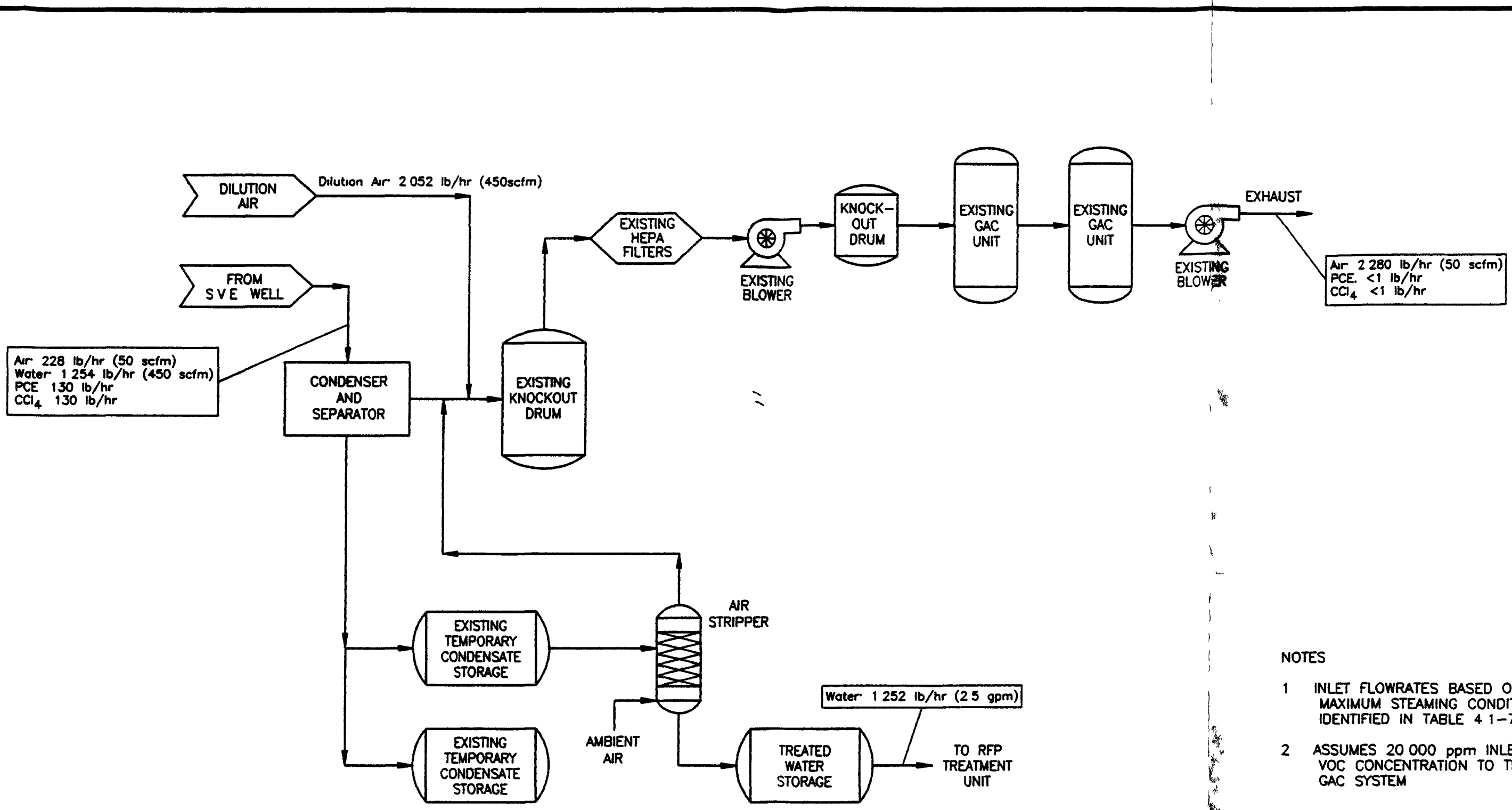
TABLE 6 2-1
ALTERNATIVE COMPARISON
(Continued)

	Commercially Available?	No of full scale units demonstrating DRE for CHCs	By-products	Unit Operations (complexity)	Expandability	Skid Size
Existing GAC with Offsite Regeneration	Yes	many	Condensate Spent GAC HEPA filters	Condenser Air stripper GAC units	add more GAC columns	
Membrane Separation	Yes		Condensate Recovered VOCs HEPA filters Spent GAC	Condenser Air stripper Compressor Condenser Membrane Module GAC units		
Ozone-UV-GAC	Yes	3 with 1 treating a small portion of CCl_4	Spent caustic HEPA filters	Cooler Photolytic reactor Aqua reactor/scrubber Ozone generator GAC units	Activated oxygen generator	10 ft x 22 ft.
Adsorption/Condensation	Yes	10	Condensate HEPA filters Recovered VOCs	Condenser Adsorbtion beds Chiller/condenser Air stripper	Modular beds - add Refrig units	7 5 ft x 12 ft.
Condensation/Refrigeration	Yes		Condensate HEPA filters Recovered VOCs Spent GAC	Condenser Air stripper Refrig condenser GAC		10 ft. X 30 ft.
Flameless Thermal Oxidizer	Yes	5 treating CHCs of which 2 are treating CCl_4	Condensate HEPA filters Spent caustic	Condenser Air stripper Flameless thermal ox Scrubber	Design in advance	8 ft. x 30 ft.

TABLE 6 2-1
ALTERNATIVE COMPARISON
(Concluded)

	Commercially Available?	No of full scale units demonstrating DRE for CHCs	By-products	Unit Operations (complexity)	Expandability	Skid Size
Thermal Oxidizer	Yes		Condensate HEPA filters Spent caustic	Condenser Air stripper Thermal oxidation Scrubber	Design in advance Retrofit is much more expensive	6 ft. x 12 ft
Catalytic Oxidizer	Yes	20 with CHCs, none with CCl_4 as primary constituent	Condensate HEPA filters Spent caustic	Condenser Air stripper Catalytic oxidation Scrubber	Oxidation chamber can be proportioned larger for more catalyst on larger frame Design in advance	4 2 ft x 8 75 ft

(4045 110-0155-571) (tbl-621) (07-01 94 9 07am)(2)



NOTES

1 INLET FLOWRATES BASED ON MAXIMUM STEAMING CONDITIONS IDENTIFIED IN TABLE 4 1-7

2 ASSUMES 20 000 ppm INLET VOC CONCENTRATION TO THE GAC SYSTEM

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Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

GAC SYSTEM
PROCESS FLOW DIAGRAM

67 of 75

FIGURE 6 2-1 MARCH 1994

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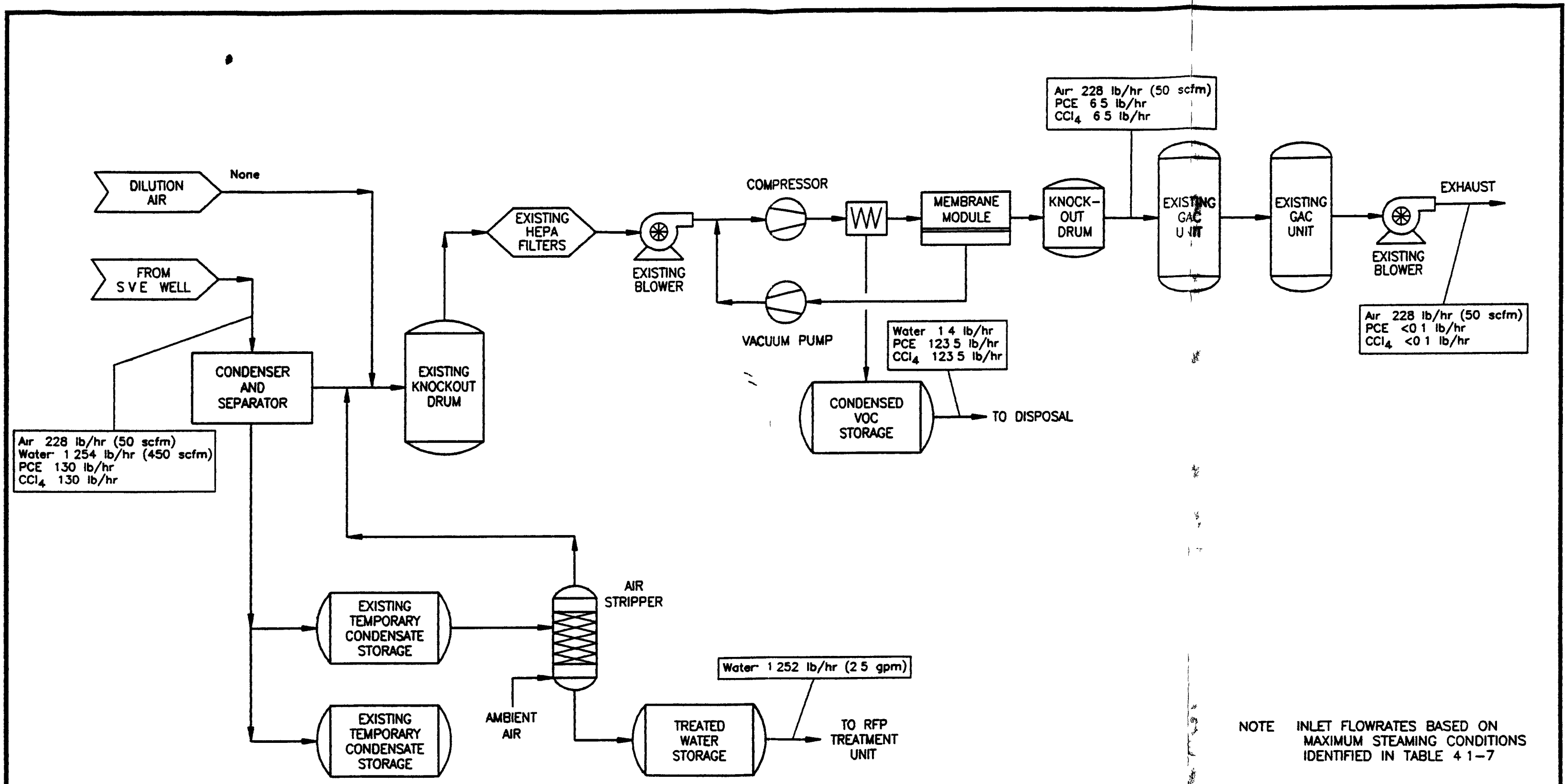

NOTE INLET FLOWRATES BASED ON MAXIMUM STEAMING CONDITIONS IDENTIFIED IN TABLE 4 1-7

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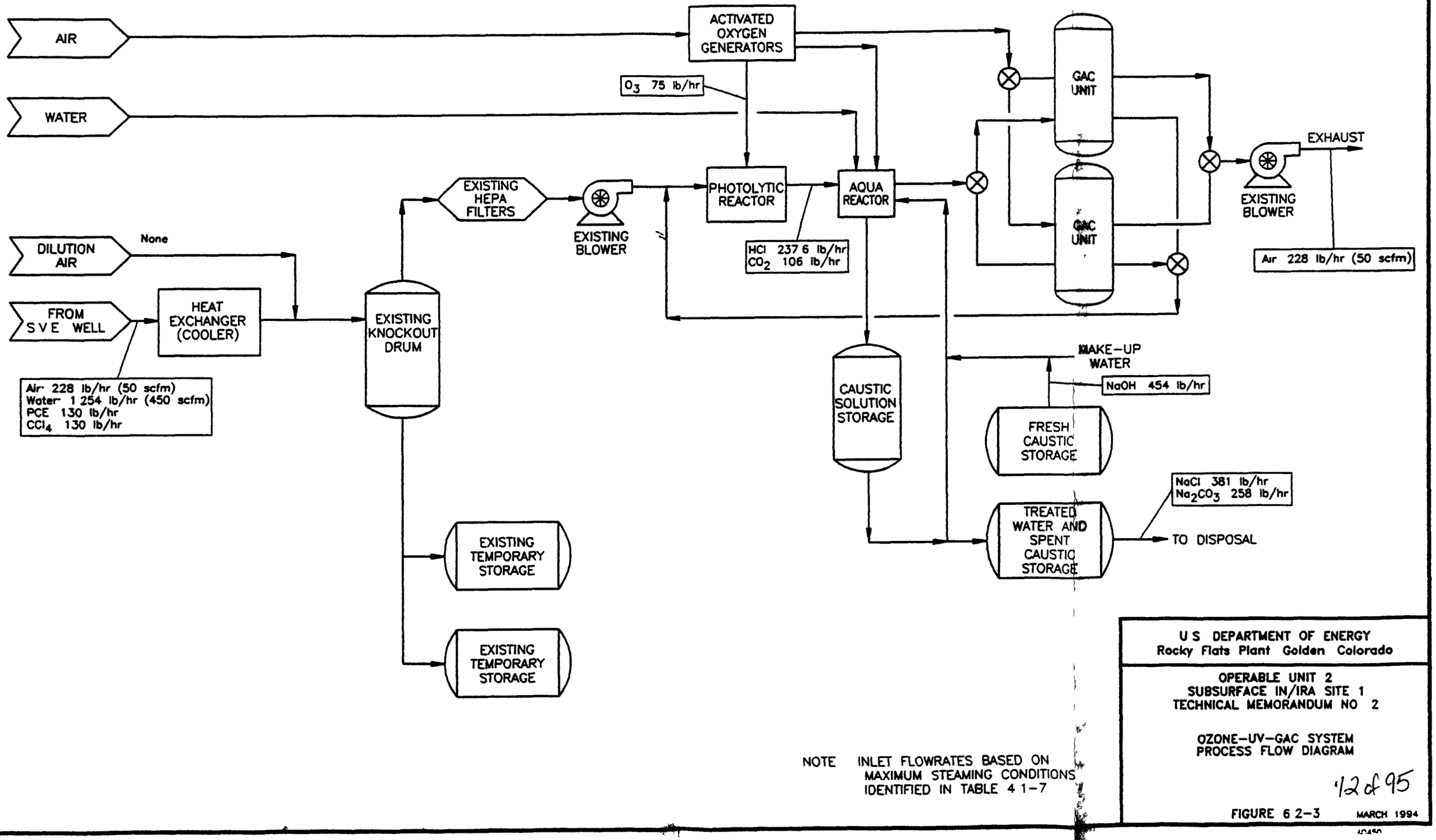
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

MEMBRANE SEPARATION SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6 2-2 MARCH 1994



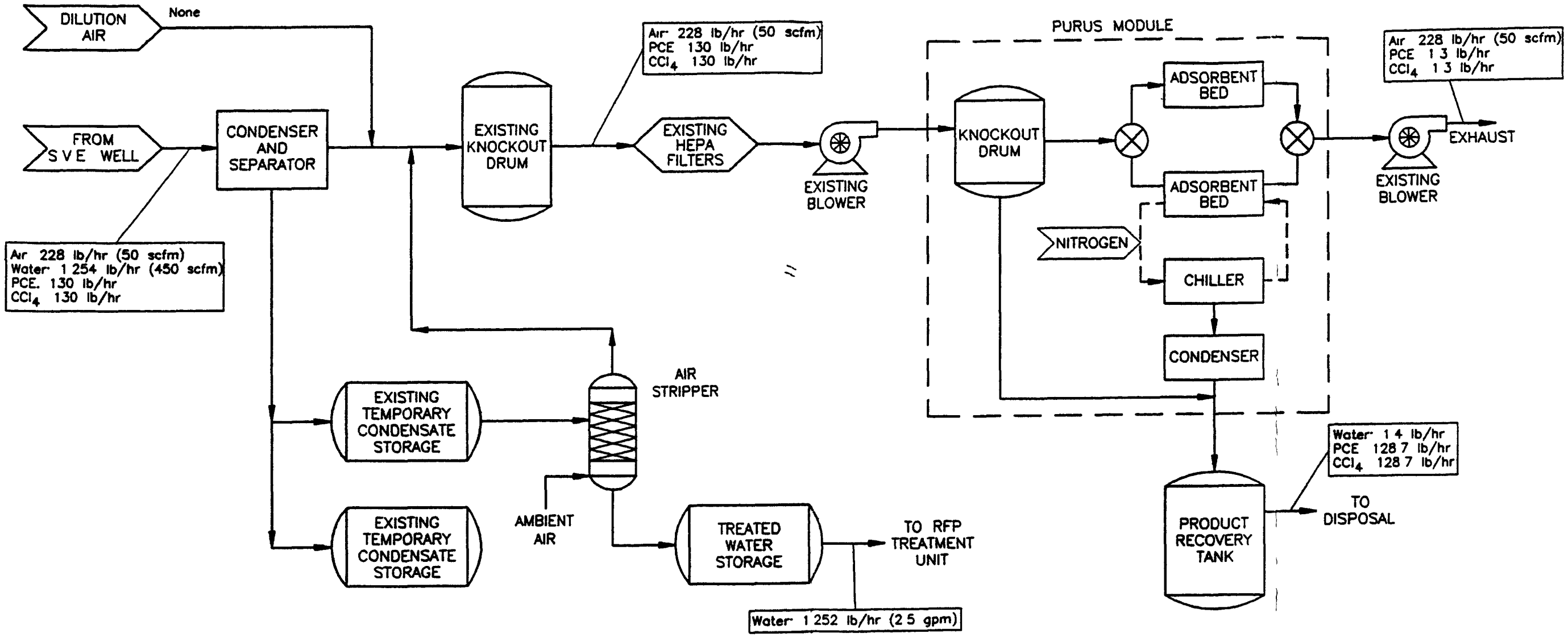
NOTE INLET FLOWRATES BASED ON MAXIMUM STEAMING CONDITIONS IDENTIFIED IN TABLE 4 1-7

U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

OZONE-UV-GAC SYSTEM
PROCESS FLOW DIAGRAM

FIGURE 6 2-3 MARCH 1994



NOTE INLET FLOWRATES BASED ON MAXIMUM STEAMING CONDITIONS IDENTIFIED IN TABLE 4 1–7

U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

ADSORPTION/CONDENSATION SYSTEM
PROCESS FLOW DIAGRAM

75 of 95

FIGURE 6 2–4 MARCH 1994

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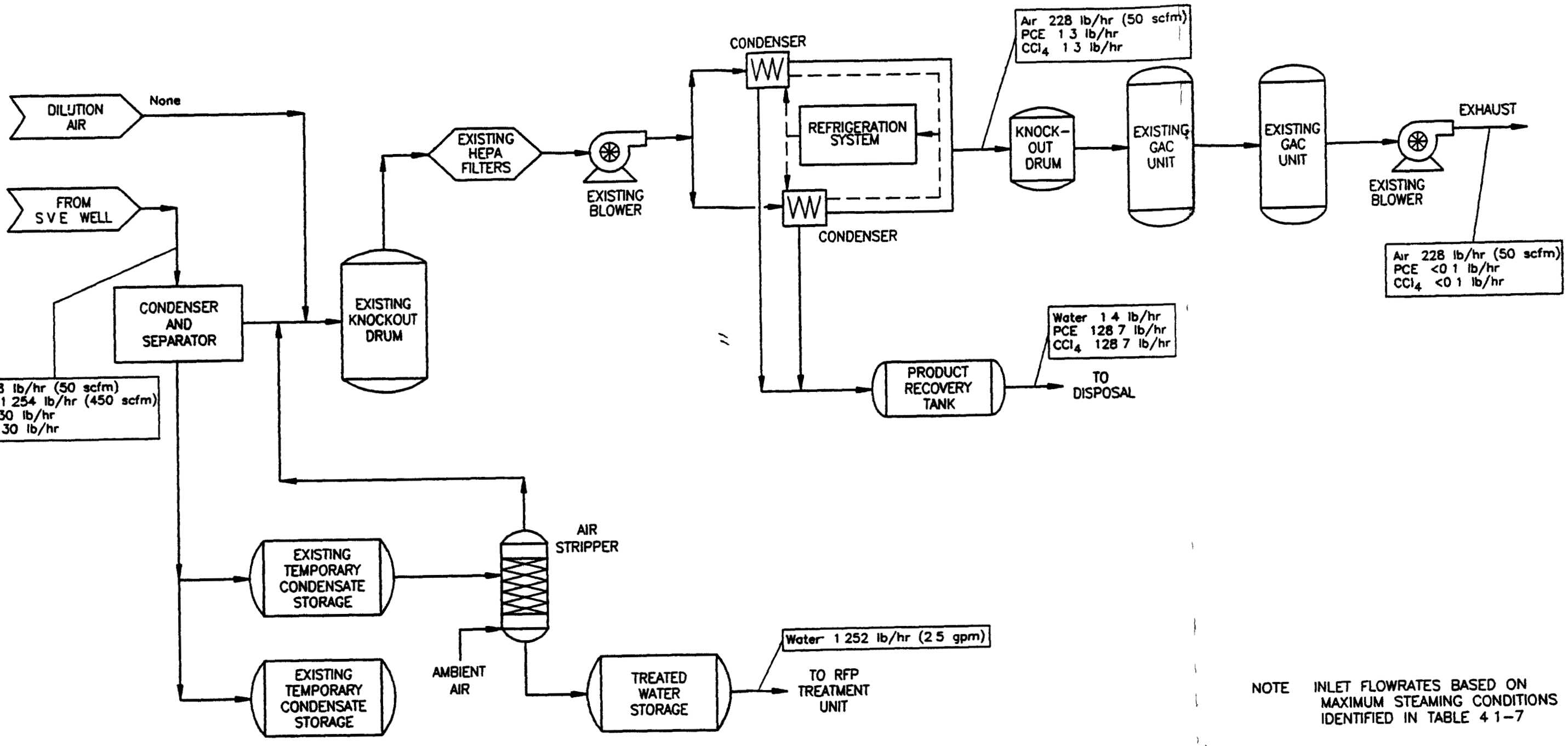


NOTE INLET FLOWRATES BASED ON MAXIMUM STEAMING CONDITIONS IDENTIFIED IN TABLE 4 1-7

U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

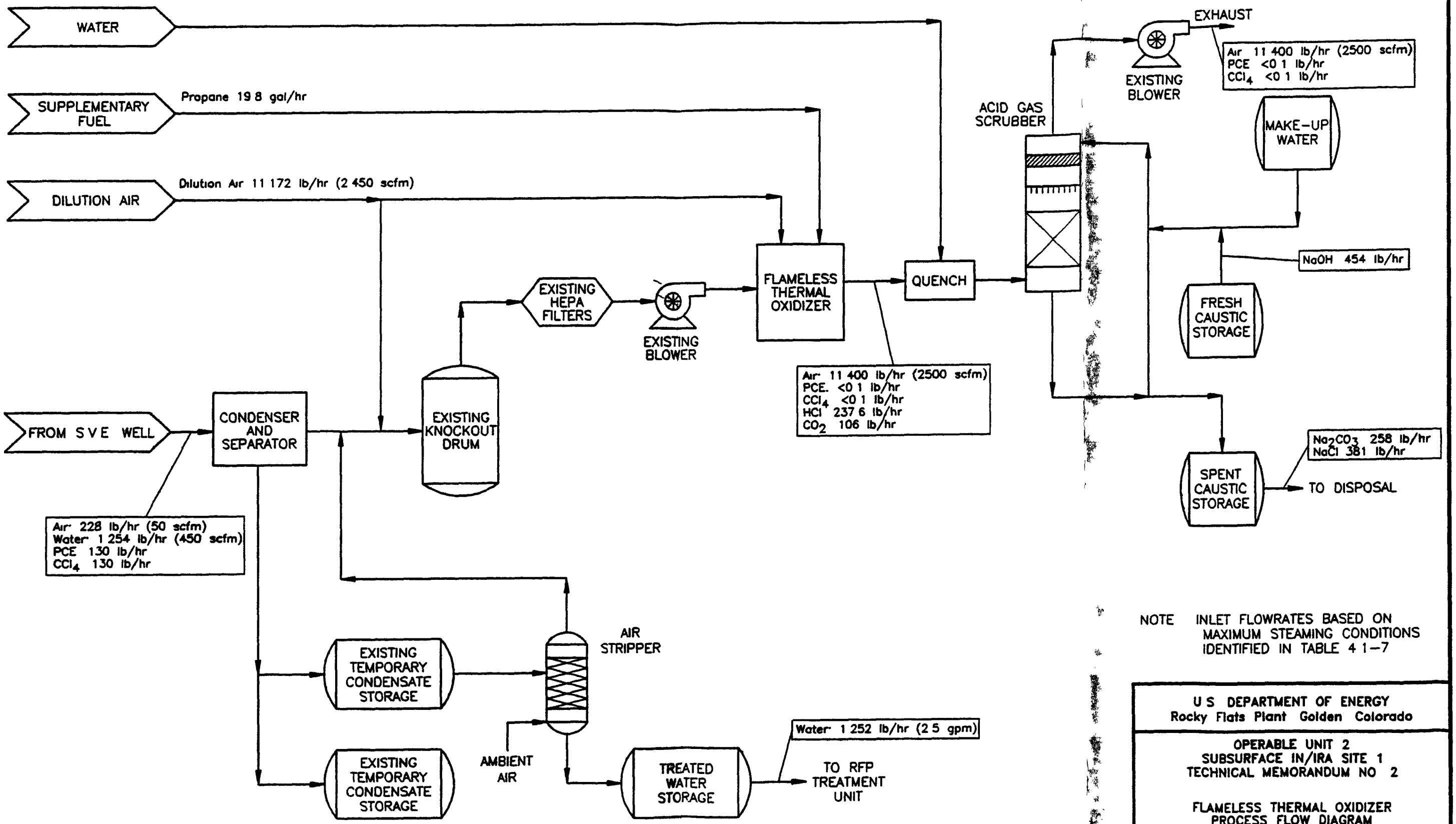
OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

CONDENSATION/REFRIGERATION SYSTEM
PROCESS FLOW DIAGRAM

78 of 95

FIGURE 6 2-5 MARCH 1994

4045009 1-1



NOTE INLET FLOWRATES BASED ON MAXIMUM STEAMING CONDITIONS IDENTIFIED IN TABLE 4 1–7

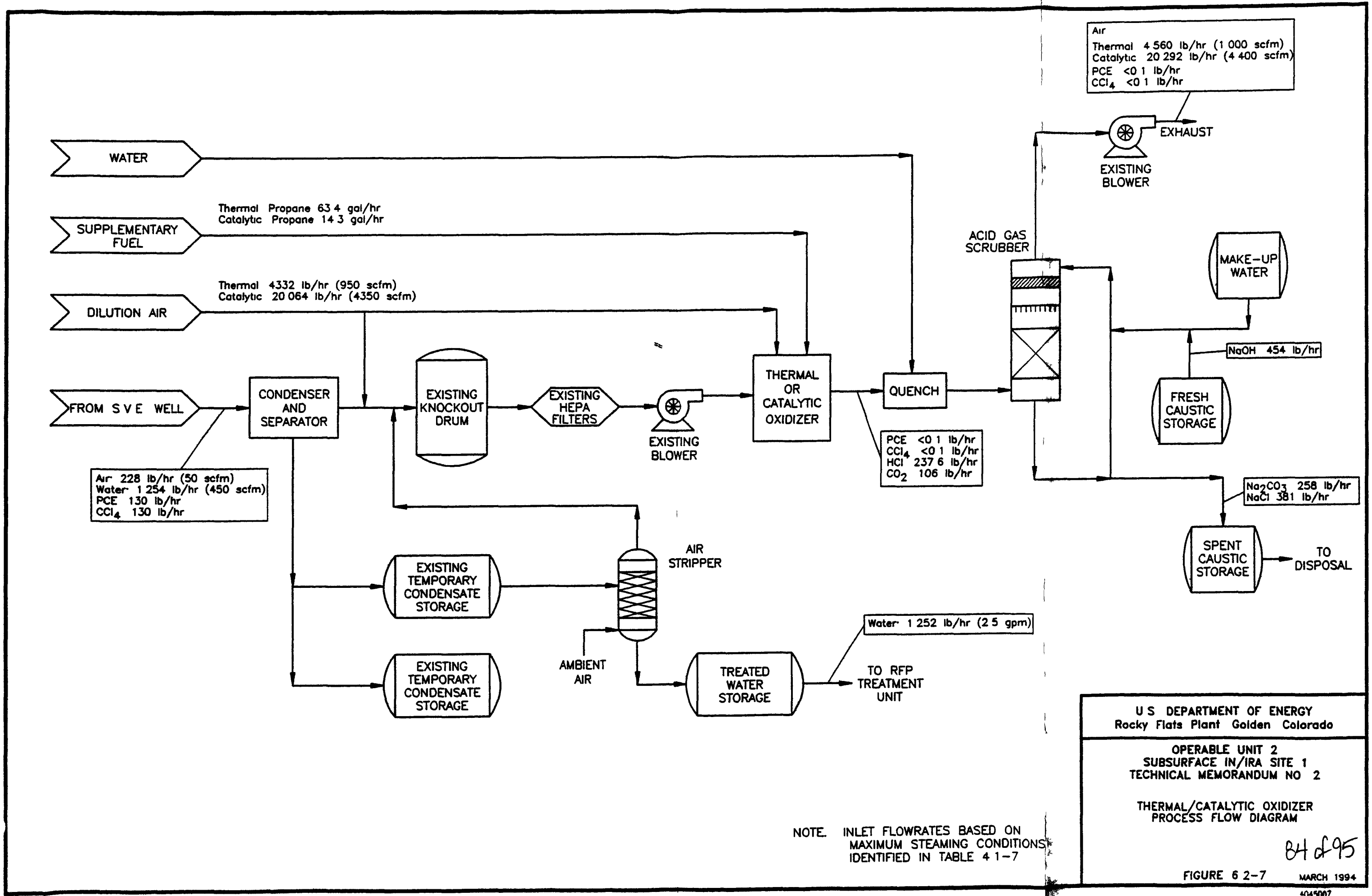
U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

FLAMELESS THERMAL OXIDIZER
PROCESS FLOW DIAGRAM

81 of 95

FIGURE 6 2–6 MARCH 1994



NOTE. INLET FLOWRATES BASED ON MAXIMUM STEAMING CONDITIONS IDENTIFIED IN TABLE 4 1-7

U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2
SUBSURFACE IN/IRA SITE 1
TECHNICAL MEMORANDUM NO 2

THERMAL/CATALYTIC OXIDIZER
PROCESS FLOW DIAGRAM

84 of 95

FIGURE 6 2-7 MARCH 1994

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